THE

OF

BOTANY

METHUEN

Frontispiece. — A Shade Plant, Jack-in-the-Pulpit

FOUNDATIONS OF BOTANY

BY

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PREFACE

This book is written upon the same plan as the author's *Elements of Botany*. A few chapters stand here but little altered from the former work, but most of them have been rewritten and considerably enlarged, and many new ones have been added. The principal changes in the book as a whole are these :

1. Most of the discussion of ecological topics is put by itself, in Part II.

2. The amount of laboratory work on the anatomy and physiology of seed-plants is considerably increased and additional experiments are introduced.

3. The treatment of spore-plants is greatly extended, so as to include laboratory work on the most important groups.

4. The meagre Flora which accompanied the earlier book has been replaced by one which contains fairly full descriptions of nearly seven hundred species of plants. Most of these are wild, but a considerable number of cultivated species have been included, mainly for the convenience of schools in large cities.

Ample material is offered for a year's course, four or five periods per week. The author is well aware that most schools devote but half a year to botany, but the tendency sets strongly toward allowing more time for this subject. Even in schools where the minimum time allowance is devoted to botany, there is a distinct advantage in being provided with a book which allows the teacher considerable option as regards the kind and amount of work which he shall offer to his classes.

Suggestions are made in the teacher's *Handbook*, which accompanies this volume, in regard to shaping half-year courses.

The latest authorities in the various departments of botany have been consulted on all doubtful points, and the attempt has been to make the book scientifically accurate throughout, yet not unduly difficult.

Most of the illustrations have been redrawn from those in standard German works of an advanced character, or drawn from nature or from photographs, expressly for this book. Besides the sources of drawings acknowledged in the author's *Elements*, many cuts have been taken from the botanies of Frank, Prantl, Detmer, Murray, and Bennett and Murray, as well as from Schimper's *Pflanzengeographie*.

Of the drawings from nature or from photographs, some figures, and Plates I, VII, and VIII, are by Mr. Edmund Garrett of Boston; several figures, the Frontispiece, and Plates II, IV, X, XI, are by Mr. Bruce Horsfall of New York; several figures are by Mr. F. Schuyler Mathews of Boston; a large number of figures and Plate V are by Mr. E. N. Fischer of Boston; several figures are by Mr. E. R. Kingsbury of Boston and Dr. J. W. Folsom of the University of Illinois.

Thanks for the use of photographs are due to Mr. H. G. Peabody of Boston (Fig. 234), to Mr. J. H. White of Boston (Figs. 32, 75, 222), to Professor Conway MacMillan of the University of Minnesota (Frontispiece), and to Professor F. V. Coville of Washington (Plate VII). Figs. 28 and 275 are taken by permission from the *Primer of Forestry*, issued by the Division of Forestry, U. S. Department of Agriculture. Figs. 263, 264, 276 are copied by permission from Professor W. J. Beal's *Seed Dispersal*, and Figs. 226, 229, 233 from Professor W. M. Davis's *Physical Geography*. Fig. 269 is from a photograph by Professor C. F. Millspaugh of Chicago. Plate IV is from a photograph by Dr. H. J. Webber.

Most of the redrawn illustrations (not microscopical) from various European sources are by Mr. Fischer. Most of the microscopical ones (and a number of figures from nature) are by Dr. J. W. Folsom of the University of Illinois, and many of both classes are by Mr. Mathews. Thanks are due to Professor J. M. Holzinger of the Winona (Minn.) State Normal School, to Professor L. Murbach of the Detroit High School, and to Mr. I. S. Cutter of Lincoln, Nebraska, for their many discriminating criticisms of the proof of Parts I and II. Mr. Samuel F. Tower of the Boston English High School, Professor Charles V. Piper of the Washington State Agricultural College, and Dr. Rodney H. True, Lecturer on Botany at Harvard University, have all read the whole or large portions of Part I and given valuable suggestions. Professor W. F. Ganong, of Smith College, has read and criticised Part II.

The chapters on spore-plants, excepting a small amount of matter retained from the *Elements of Botany*, are entirely the work of Mr. A. B. Seymour of the Cryptogamic Herbarium of Harvard University.

The author has attempted to steer a middle course between the advocates of the out-of-door school and of the histological school of botany teaching. He has endeavored never to use a technical term where he could dispense with it, and on the other hand, not to become inexact by shunning necessary terms. In deciding questions of this sort, *a priori* reasoning is of little value ; one must ascertain by repeated trials how much of a technical vocabulary the average beginner in botany can profitably master. The teacher who has discovered that not one of the boys in a division of thirty-six pupils knows that his own desk-top is of cherry wood may well hesitate about beginning his botany teaching with a discourse on centrospheres and karyokinesis. It has been assumed throughout this book that, other things being equal, the knowledge is of most worth which touches the pupil's daily life at the most points, and therefore best enables him to understand his own environment. On the other hand, the author has no sympathy with those who decry the use of apparatus in botany teaching in secondary schools and who would confine the work of their pupils mainly within the limits of what can be seen with the unaided eye. If the compound microscope plainly reveals things shown only imperfectly by a magnifier and not seen at all with the naked eye, — use the microscope! If iodine solution or other easily prepared reagents make evident the existence of structures or substances not to be detected without them, — then use the reagents! No one thinks of denying a boy the use of a spyglass or a compass for his tramps afield or his outings in a boat because he has not studied physics. No one would refuse to let an intelligent boy or girl use a camera because the would-be photographer had not mastered the chemical reactions that follow upon the exposure of a sensitized plate. Yet it is equally illogical to defer some of the most fascinating portions of botanical study until the college course, to which most never attain. When the university professor tells the teacher that he ought not to employ the ordinary appliances of elementary biological investigation in the school laboratory because the pupils cannot intelligently use them, the teacher is forced to reply that the professor himself cannot intelligently discuss a subject of which he has no personal knowledge. The pupils are deeply interested; they prove by their drawings and their recitations that they have seen a good way into plant structures and plant functions; then why not let them study botany in earnest?

J. Y. B.

Cambridge, January, 1901.

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FOUNDATIONS OF BOTANY

INTRODUCTION

"Botany is the science which endeavors to answer every reasonable question about plants."[1]

The plant is a living being, provided generally with many parts, called *organs*, which it uses for taking in nourishment, for breathing, for protection against its enemies, and for reproducing itself and so keeping up the numbers of its own kind. The study of the individual plant therefore embraces a variety of topics, and the examination of its relation to others introduces many more subjects.

Morphology, or the science of form, structure, and so on, deals with the plant without much regard to its character as a living thing. Under this head are studied the forms of plants and the various shapes or disguises which the same sort of organ may take in different kinds of plants, their gross structure, their microscopical structure, their classification, and the successive stages in the development of the individual plant.

Plant Physiology treats of the plant in action, how it lives, breathes, feeds, grows, and produces others like itself.

Geographical Distribution, or botanical geography, discusses the range of the various kinds of plants over the

[1] Professor George L. Goodale.

earth's surface. Another subdivision of botany, usually studied along with geology, describes the history of plant life on the earth from the appearance of the first plants until the present time.

Systematic Botany, or the classification of plants, should naturally follow the examination of the groups of seed-plants and spore-plants.

Plant Ecology treats of the relations of the plant to the conditions under which it lives. Under this division of the science are studied the effects of soil, climate, and friendly or hostile animals and plants on the external form, the internal structure, and the habits of plants. This is in many respects the most interesting department of botany, but it has to be studied for the most part out of doors.

Many of the topics suggested in the above outline cannot well be studied in the high school. There is not usually time to take up more than the merest outline of botanical geography, or to do much more than mention the important subject of *Economic Botany* — the study of the uses of plants to man. It ought, however, to be possible for the student to learn in his high-school course a good deal about the simpler facts of morphology and of vegetable physiology. One does not become a botanist — not even much of an amateur in the subject — by reading books about botany. It is necessary to study plants themselves, to take them to pieces and make out the connection of their parts, to examine with the microscope small portions of the exterior surface and thin slices of all the variously built materials or *tissues* of which the plant consists. All this can be done with living specimens or with those taken from dead parts of plants that have been preserved in any suitable way, as by drying or by placing in alcohol or other fluids which prevent decay. Living plants must be studied in order to ascertain what kinds of food they take, what kinds of waste substances they excrete, how and where their growth takes place and what circumstances favor it, how they move, and indeed to get as complete an idea as possible of what has been called the behavior of plants.

Since the most familiar and most interesting plants spring from seeds, the beginner in botany can hardly do better than to examine at the outset the structure of a few familiar seeds, then sprout them and watch the growth of the seedlings which spring from them. Afterwards he may study in a few typical examples the organs, structure, and functions of seed-plants, trace their life history, and so, step by step, follow the process by which a new crop of seeds at last results from the growth and development of such a seed as that with which he began.

After he has come to know in a general way about the structure and functions of seed-plants, the student may become acquainted with some typical cryptogams or spore-plants. There are so many groups of these that only a few representative ones can be chosen for study.

PART I

STRUCTURE, FUNCTIONS, AND CLASSIFICATION OF PLANTS

CHAPTER I

THE SEED AND ITS GERMINATION

1. Germination of the Squash Seed. — Soak some squash seeds in tepid water for twelve hours or more. Plant these about an inch deep in damp sand or pine sawdust or peat-moss in a wooden box which has had holes enough bored through the bottom so that it will not hold water. Put the box in a warm place (not at any time over 70° or 80° Fahrenheit),[1] and cover it loosely with a board or a pane of glass. Keep the sand or sawdust moist, but not wet, and the seeds will germinate. As soon as any of the seeds, on being dug up, are found to have burst open, sketch one in this condition,[2] noting the manner in which the outer seed-coat is split, and continue to examine the seedlings at intervals of two days, until at least eight stages in the growth of the plantlet have been noted.[3]

[1] Here and elsewhere throughout the book temperatures are expressed in Fahrenheit degrees, since with us, unfortunately, the Centigrade scale is not the familiar one, outside of physical and chemical laboratories.

[2] The student need not feel that he is expected to make finished drawings to record what he sees, but some kind of careful sketch, if only the merest outline, is indispensable. Practice and study of the illustrations hereafter given will soon impart some facility even to those who have had little or no instruction in drawing. Consult here Figs. 9 and 89.

[3] The class is not to wait for the completion of this work (which may, if desirable, be done by each pupil at home), but is to proceed at once with the examination of the squash seed and of other seeds, as directed in the following sections, and to set some beans, peas, and corn to sprouting, so that they may be studied at the same time with the germinating squashes.

Observe particularly how the sand is pushed aside by the rise of the young seedlings. Suggest some reason for the manner in which the sand is penetrated by the rising stem.

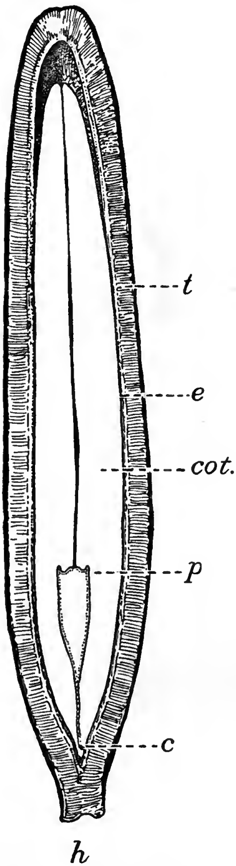


FIG. 1.—Lengthwise Section of a Squash Seed. (Magnified about five times.)

2. Examination of the Squash Seed.—Make a sketch of the dry seed, natural size. Note the little scar at the pointed end of the seed where the latter was attached to its place of growth in the squash. Label this *hilum*.

Note the little hole in the hilum; it is the *micropyle*, seen most plainly in a soaked seed. (If there are two depressions on the hilum the deeper one is the micropyle.)

Describe the color and texture of the outer coating of the seed. With a scalpel or a very sharp knife cut across near the middle a seed that has been soaked in water for twenty-four hours. Squeeze one of the portions, held edgewise between the thumb and finger, in such a way as to separate slightly the halves into which the contents of the seed is naturally divided. Examine with the magnifying glass the section thus treated, make a sketch of it, and label the shell or covering of the seed and the kernel within this.

Taking another soaked seed, chip away the white outer shell, called the *testa*, and observe the thin, greenish inner skin (Fig. 1, *e*), with which the kernel of the seed is closely covered.[1]

Strip this off and sketch the uncovered kernel or *embryo*. Note that at one end it tapers to a point. This pointed portion, known as the *hypocotyl*, will develop after the seed sprouts into the stem of the plantlet, like that shown at *c* in Fig. 2.

Split the halves of the kernel entirely apart from each other,

[1] See footnote 2 to Sect. 18.

noticing that they are only attached for a very little way next to the hypocotyl, and observe the thickness of the halves and the slight unevenness of the inner surfaces. These halves are called seed-leaves or *cotyledons.*

Have ready some seeds which have been soaked for twenty-four hours and then left in a loosely covered jar on damp blotting paper at a temperature of 70° or over until they have begun to sprout.

Split one of these seeds apart, separating the cotyledons, and observe, at the junction of these, two very slender pointed objects, the rudimentary leaves of the *plumule* or first bud (Fig. 1, *p*).

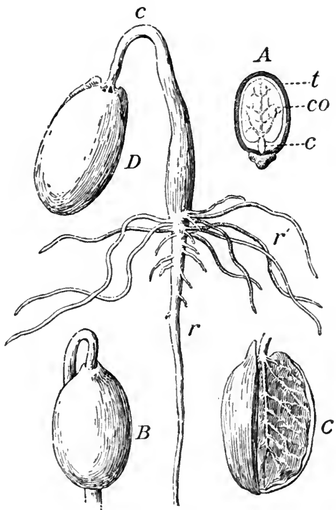


FIG. 2.—The Castor Bean and its Germination.

A, longitudinal section of ripe seed; *t*, testa; *co*, cotyledon; *c*, hypocotyl; *B*, sprouting seed covered with endosperm; *C*, same, with half of endosperm removed; *D*, seedling; *r*, primary root; *r'*, secondary roots; *c*, arch of hypocotyl.

3. Examination of the Bean.—Study the seed, both dry and after twelve hours' soaking, in the same general way in which the squash seed has just been examined.[1]

Notice the presence of a distinct plumule, consisting of a pair of rudimentary leaves between the cotyledons, just where they are joined to the top of the hypocotyl. In many seeds (as the pea) the plumule does not show distinct leaves. But in all cases the plumule contains the *growing point*, the tip of the stem from which all the upward growth of the plant is to proceed.

Make a sketch of these leaves as they lie in place on one of the cotyledons, after the bean has been split open.

[1] The larger the variety of bean chosen, the easier it will be to see and sketch the several parts. The large red kidney bean, the horticultural bean, or the lima bean will do well for this examination.

Note the cavity in each cotyledon caused by the pressure of the plumule and of the hypocotyl.

4. Examination of the Pea. — There are no very important points of difference between the bean and pea, so far as the structure of the seed is concerned, but the student should rapidly dissect a few soaked peas to get an idea of the appearance of the parts, since he is to study the germination of peas in some detail.

Make only one sketch, that of the hypocotyl as seen in position after the removal of the seed-coats.[1]

5. Germination of the Bean or the White Lupine, the Pea, and the Grain of Corn. — Soak some beans or lupine seeds as directed in Section 3, plant them,[2] and make a series of sketches on the same general plan as those in Fig. 9.

Follow the same directions with some peas and some corn. In the case of the corn, make six or more sketches at various stages to illustrate the growth of the plumule and the formation of roots; first a main root from the base of the hypocotyl, then others more slender from the same region, and later on still others from points higher up on the stem (see Fig. 15). The student may be able to discover what becomes of the large outer part of the embryo. This is really the single cotyledon of the corn (Fig. 6). It does not as a whole rise above ground, but most of it remains in the buried grain, and acts as a digesting and absorbing organ through which the endosperm or food stored outside of the embryo is transferred into the growing plant, as fast as it can be made liquid for that purpose.

6. Germination of the Horse-Chestnut. — Plant some seeds of the horse-chestnut or the buckeye, study their mode of germination, and observe the nature and peculiar modifications of the parts.

Consult Gray's *Structural Botany*, Vol. I, pp. 19, 20.

7. Conditions Requisite for Germination. — When we try to enumerate the external conditions which can affect

[1] The teacher will find excellent sketches of most of the germinating seeds described in the present chapter in Miss Newell's *Outlines of Lessons in Botany*, Part I.

[2] The pupil may economize space by planting the new seeds in boxes from which part of the earlier planted seeds have been dug up for use in sketching, etc.

germination, we find that the principal ones are heat, moisture, and presence of air. A few simple experiments will show what influence these conditions exert.

8. Temperature. — Common observation shows that a moderate amount of warmth is necessary for the sprouting of seeds. Every farmer or gardener knows that during a cold spring many seeds, if planted, will rot in the ground. But a somewhat exact experiment is necessary to show what is the best temperature for seeds to grow in, and whether variations in the temperature make more difference in the quickness with which they begin to germinate or in the total per cent which finally succeed.

EXPERIMENT I

Relation of Temperature to Germination. — Prepare at least four teacups or tumblers, each with wet soft paper packed in the bottom to a depth of nearly an inch. Have a tightly fitting cover over each. Put in each vessel the same number of soaked peas. Stand the vessels with their contents in places where they will be exposed to different, but fairly constant, temperatures, and observe the several temperatures carefully with a thermometer. Take pains to keep the tumblers in the warm places from drying out, so that their contents will not be less moist than that of the others. The following series is merely suggested, — other values may be found more convenient. Note the rate of germination in each place and record in tabular form as follows:

No. of seeds sprouted in	24 hrs.	48 hrs.	72 hrs.	96 hrs.	etc.
At 32°,	——	——	——	——	——
At 50°,	——	——	——	——	——
At 70°,	——	——	——	——	——
At 90°,[1]	——	——	——	——	——

[1] For the exact regulation of the temperatures a thermostat (see *Handbook*) is desirable. If one is available, a maximum temperature of 100° or over should be tried.

9. Moisture. — What was said in the preceding section in regard to temperature applies also to the question of the best conditions for germination as regards the supply of moisture. The soil in which seeds grow out of doors is always moist; it rests with the experimenter to find out approximately what is the best amount of moisture.

EXPERIMENT II[1]

Relation of Water to Germination. — Arrange seeds in several vessels as follows:

In the first put blotting paper that is barely moistened; on this put some dry seeds.

In the second put blotting paper that has been barely moistened; on this put seeds that have been soaked for twenty-four hours.

In the third put water enough to soak the paper thoroughly; use soaked seeds.

In the fourth put water enough to half cover the seeds.

Place the vessels where they will have same temperature and note the time of germination.

Tabulate your results as in the previous experiment.

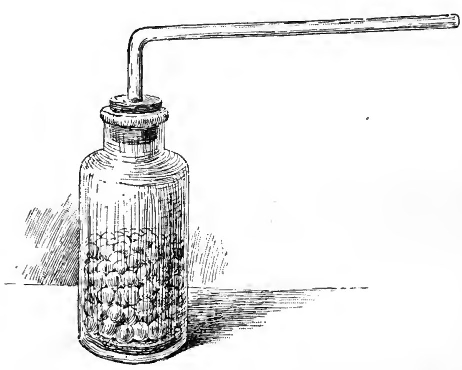


FIG. 3.—Soaked Peas in Stoppered Bottle, ready for Exhaustion of Air.

10. Relation of the Air Supply to Germination. — If we wish to see how soaked seeds will behave with hardly any air supply, it is necessary to place them in a bottle arranged

[1] This may be made a home experiment.

as shown in Fig. 3, exhaust the air by connecting the glass tube with an air-pump, which is then pumped vigorously, and seal the tube while the exhaustion is going on. The sealing is best done by holding a Bunsen flame under the middle of the horizontal part of the tube. A much easier experiment, which is nearly as satisfactory, can, however, be performed without the air-pump.

EXPERIMENT III

Will Seeds Germinate well without a Good Supply of Air? — Place some soaked seeds on damp blotting paper in the bottom of a bottle, using seeds enough to fill it three-quarters full, and close tightly with a rubber stopper.

Place a few other seeds of the same kind in a second bottle; cover loosely.

Place the bottles side by side, so that they will have the same conditions of light and heat. Watch for results, and tabulate as in previous experiments.

Most seeds will not germinate under water, but those of the sunflower will do so, and therefore Exp. III may be varied in the following manner:

Remove the shells carefully from a considerable number of sunflower seeds.[1] Try to germinate one lot of these in water which has been boiled in a flask to remove the air, and then cooled in the same flask. Over the water, with the seeds in it, a layer of cotton-seed oil about a half inch deep is poured, to keep the water from contact with air. In this bottle then there will be only seeds and air-free water. Try to germinate another lot of seeds in a bottle half filled with ordinary water, also covered with cotton-seed oil. Results?

11. Germination involves Chemical Changes.— If a thermometer is inserted into a jar of sprouting seeds, for

[1] These are really fruits, but the distinction is not an important one at this time.

instance peas, in a room at the ordinary temperature, the peas will be found to be warmer than the surrounding air. This rise of temperature is at least partly due to the absorption from the air of that substance in it which supports the life of animals and maintains the burning of fires, namely, *oxygen.*

The union of oxygen with substances with which it can combine, that is with those which will burn, is called *oxidation.* This kind of chemical change is universal in plants and animals while they are in an active condition, and the energy which they manifest in their growth and movements is as directly the result of the oxidation going on inside them as the energy of a steam engine is the result of the burning of coal or other fuel under its boiler. In the sprouting seed much of the energy produced by the action of oxygen upon oxidizable portions of its contents is expended in producing growth, but some of this energy is wasted by being transformed into heat which escapes into the surrounding soil. It is this escaping heat which is detected by a thermometer thrust into a quantity of germinating seeds.

EXPERIMENT IV

Effect of Germinating Seeds upon the Surrounding Air. — When Exp. III has been finished, remove a little of the air from above the peas in the first bottle. This can easily be done with a rubber bulb attached to a short glass tube. Then bubble this air through some clear, filtered limewater. Also blow the breath through some limewater by aid of a short glass tube. Explain any similarity in results obtained. (Carbon dioxide turns limewater milky.) Afterwards insert into the air above the peas in the same bottle a lighted pine splinter, and note the effect upon its flame.

12. Other Proofs of Chemical Action. — Besides the proof of chemical changes in germinating seeds just described, there are other kinds of evidence to the same effect.

Malt, which is merely sprouted barley with its germination permanently stopped at the desired point by the application of heat, tastes differently from the unsprouted grain, and can be shown by chemical tests to have suffered a variety of changes. If you can get unsprouted barley and malt, taste both and see if you can decide what substance is more abundant in the malt.

Germinating kernels of corn undergo great alterations in their structure; the starch grains are gradually eaten away until they are ragged and full of holes and finally disappear.

13. The Embryo and its Development. — The miniature plant, as it exists ready formed and alive but inactive in the seed, is called the *embryo*. In the seeds so far examined, practically the entire contents of the seed-coats consist of the embryo, but this is not the case with the great majority of seeds, as will be shown in the following chapter.

CHAPTER II

STORAGE OF FOOD IN THE SEED

14. Food in the Embryo. — Squash seeds are not much used for human food, though both these and melon seeds are occasionally eaten in parts of Europe; but beans and peas are important articles of food. Whether the material accumulated in the cotyledons is an aid to the growth of the young plant may be learned from a simple experiment.

15. Mutilated and Perfect Seedlings. — One of the best ways in which to find out the importance and the special use of any part of a plant is to remove the part in question and see how the plant behaves afterward.

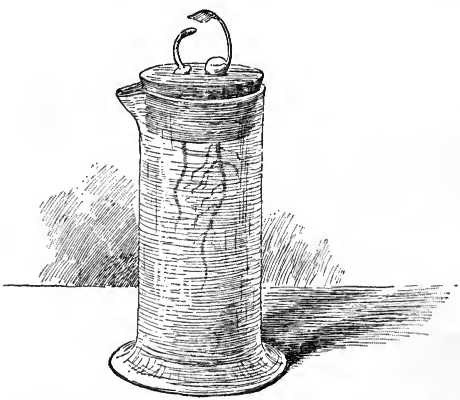


FIG. 4. — Germinating Peas, growing in Water, one deprived of its Cotyledons.

EXPERIMENT V[1]

Are the Cotyledons of a Pea of any Use to the Seedling? — Sprout several peas on blotting paper. When the plumules appear, carefully cut away the cotyledons from some of the seeds. Place on a perforated cork, as shown in Fig. 4, one or two seedlings from

[1] May be a home experiment.

which the cotyledons have been cut, and as many which have not been mutilated, and allow the roots to extend into the water. Let them grow for some days, or even weeks, and note results.

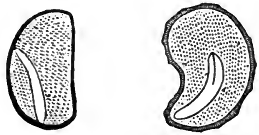
16. Food stored in Seeds in Relation to Growth after Germination. — If two kinds of seeds of somewhat similar character, one kind large and the other small, are allowed to germinate and grow side by side, some important inferences may be drawn from their relative rate of growth.

EXPERIMENT VI[1]

Does the Amount of Material in the Seed have anything to do with the Rate of Growth of the Seedling? — Germinate ten or more clover seeds, and about the same number of peas, on moist blotting paper under a bell-jar. After they are well sprouted, transfer both kinds of seeds to fine cotton netting, stretched across wide-mouthed jars nearly full of water. The roots should dip into the water, but the seeds must not do so. Allow the plants to grow until the peas are from four to six inches high.

Some of the growth in each case depends on material gathered from the air and water, but most of it, during the very early life of the plant, is due to the reserve material stored in the seed. Where is it in the seeds so far studied? Proof?

17. Storage of Food outside of the Embryo. — In very many cases the cotyledons contain little food, but there is a supply of it stored in the seed beside or around them (Figs. 2, 5, and 6).



I II

FIG. 5. — Seeds with Endosperm, Longitudinal Sections.

I, asparagus (magnified).
II, poppy (magnified).

18. Examination of the Four-o'clock Seed. — Examine the external surface of a seed[2] of the four-o'clock, and try the hardness of

[1] May be a home experiment. [2] Strictly speaking, a fruit.

the outer coat by cutting it with a knife. From seeds which have been soaked in water at least twenty-four hours peel off the coatings and sketch the kernel. Make a cross-section of one of the soaked seeds which has not been stripped of its coatings, and sketch the section as seen with the magnifying glass, to show the parts, especially the two cotyledons, lying in close contact and encircling the white, starchy-looking *endosperm*.[1]

The name *endosperm* is applied to food stored in parts of the seed other than the embryo.[2] With a mounted needle pick out the little almost spherical mass of endosperm from inside the cotyledons of a seed which has been deprived of its coats, and sketch the embryo, noting how it is curved so as to enclose the endosperm almost completely.

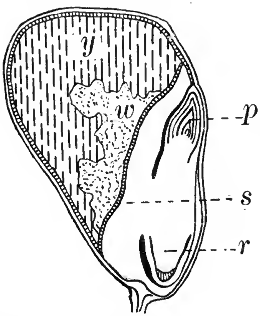


FIG. 6. — Lengthwise Section of Grain of Corn. (Magnified about three times.)

y, yellow, oily part of endosperm; *w*, white, starchy part of endosperm; *p*, plumule; *s*, the shield (cotyledon), in contact with the endosperm for absorption of food from it; *r*, the primary root.

19. Examination of the Kernel of Indian Corn. — Soak some grains of large yellow field corn[3] for about three days.

Sketch an unsoaked kernel, so as to show the grooved side, where the germ lies. Observe how this groove has become partially filled up in the soaked kernels.

Remove the thin, tough skin from one of the latter, and notice its transparency. This skin — the bran of unsifted corn meal — does not exactly correspond to the testa and inner coat of ordinary seeds, since the kernel of corn, like all other grains (and like the seed of the four-o'clock), represents not merely the seed, but also the seed-vessel in which it was formed and grew, and is therefore a fruit.

1 Buckwheat furnishes another excellent study in seeds with endosperm. Like that of the four-o'clock, it is, strictly speaking, a fruit; so also is a grain of corn.

2 In the squash seed the green layer which covered the embryo represents the remains of the endosperm.

3 The varieties with long, flat kernels, raised in the Middle and Southern States under the name of "dent corn," are the best.

Cut sections of the soaked kernels, some transverse, some lengthwise and parallel to the flat surfaces, some lengthwise and at right angles to the flat surfaces. Try the effect of staining some of these sections with iodine solution.

Make a sketch of one section of each of the three kinds, and label the dirty white portion, of cheesy consistency, *embryo;* and the yellow portions, and those which are white and floury, *endosperm.*

Chip off the endosperm from one kernel so as to remove the embryo free from other parts.[1] Notice its form, somewhat triangular in outline, sometimes nearly the shape of a beechnut, in other specimens nearly like an almond.

Estimate what proportion of the entire bulk of the soaked kernel is embryo.

Split the embryo lengthwise so as to show the slender, somewhat conical plumule.[2]

20. Corn Seedlings deprived of Endosperm. — An experiment parallel to No. V serves to show the function and the importance of the endosperm of Indian corn.

EXPERIMENT VII

Of how much Use to the Corn Seedling is the Endosperm ? — Sprout kernels of corn on blotting paper. When they get fairly started, cut away the endosperm carefully from several of the seeds. Suspend on mosquito netting on the surface of water in the same jar two or three seedlings which have had their endosperm removed, and as many which have not been mutilated. Let them grow for some weeks, and note results.

21. Starch. — Most common seeds contain starch. Every one knows something about the appearance of ordi-

[1] The embryo may be removed with great ease from kernels of rather mature green corn. Boil the corn for about twenty minutes on the cob, then pick the kernels off one by one with the point of a knife. They may be preserved indefinitely in alcohol of 50 or 75%.

[2] The teacher may well consult Figs. 56–61, inclusive, in Gray's *Structural Botany.*

nary commercial starch as used in the laundry, and as sold for food in packages of cornstarch. When pure it is characterized not only by its lustre, but also by its peculiar velvety feeling when rubbed between the fingers.

22. The Starch Test. — It is not always easy to recognize at sight the presence of starch as it occurs in seeds, but it may be detected by a very simple chemical test, namely, the addition of a solution of iodine.[1]

EXPERIMENT VIII[2]

Examination of Familiar Seeds with Iodine. — Cut in two with a sharp knife the seeds to be experimented on, then pour on each, drop by drop, some of the iodine solution. Only a little is necessary; sometimes the first drop is enough.

If starch is present, a blue color (sometimes almost black) will appear. If no color is obtained in this way, boil the pulverized seeds for a moment in a few drops of water, and try again.

Test in this manner corn, wheat (in the shape of flour), oats (in oatmeal), barley, rice, buckwheat, flax, rye, sunflower, four-o'clock, morning-glory, mustard seed, beans, peanuts, Brazil-nuts, hazelnuts, and any other seeds that you can get. Report your results in tabular form as follows:

Much Starch	Little Starch	No Starch
Color: blackish or dark blue.	Color: pale blue or greenish.	Color: brown, orange, or yellowish.

23. Microscopical Examination of Starch.[3] — Examine starch in water with a rather high power of the microscope (not less than 200 diameters).

[1] The tincture of iodine sold at the drug-stores will do, but the solution prepared as directed in the *Handbook* answers better. This may be made up in quantity, and issued to the pupils in drachm vials, to be taken home and used there, if the experimenting must be done outside of the laboratory or the schoolroom.

[2] May be a home experiment.

[3] At this point the teacher should give a brief illustrated talk on the construction and theory of the compound microscope.

Pulp scraped from a potato, that from a canna rootstock, wheat flour, the finely powdered starch sold under the commercial name of "cornstarch" for cooking, oatmeal, and buckwheat finely powdered in a mortar, will furnish excellent examples of the shape and markings of starch grains. Sketch all of the kinds examined, taking pains to bring out the markings.[1] Compare the sketches with Figs. 7 and 8.

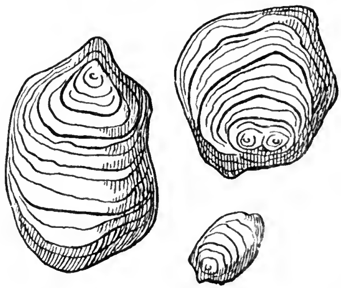


FIG. 7. — Canna Starch. (Magnified 300 diameters.)

With a medicine-dropper or a very small pipette run in a drop of iodine solution under one edge of the cover-glass, at the same time withdrawing a little water from the margin opposite by touching to it a bit of blotting paper.

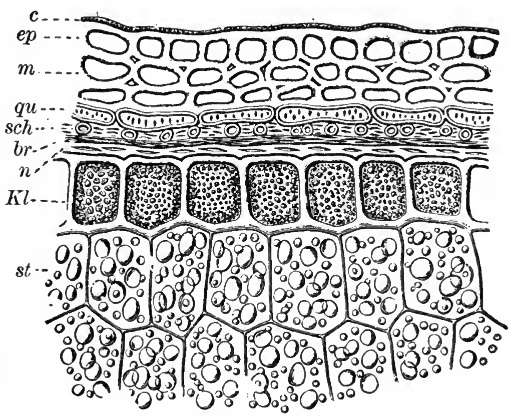


FIG. 8. — Section through Exterior Part of a Grain of Wheat.

c, cuticle or outer layer of bran; *ep*, epidermis; *m*, layer beneath epidermis; *qu*, *sch*, layers of hull next to seed-coats; *br*, *n*, seed-coats; *Kl*, layer containing proteid grains; *st*, cells of the endosperm filled with starch. (Greatly magnified.)

[1] The markings will be seen more distinctly if care is taken not to admit too much light to the object. Rotate the diaphragm beneath the stage of the microscope, or otherwise regulate the supply of light, until the opening is found which gives the best effect.

Examine again and note the blue coloration of the starch grains and the unstained or yellow appearance of other substances in the field. Cut very thin slices from beans, peas, or kernels of corn; mount in water, stain as above directed, and draw as seen under the microscope. Compare with Figs. 7 and 8.[1] Note the fact that the starch is not packed away in the seeds in bulk, but that it is enclosed in little chambers or *cells*.

24. Plant-Cells. — Almost all the parts of the higher plants are built up of little separate portions called *cells*. The cell is the unit of plant-structure, and bears something the same relation to the plant of which it is a part that one cell of a honeycomb does to the whole comb. But this comparison is not a perfect one, for neither the waxen wall of the honeycomb-cell nor the honey within it is alive, while every plant-cell is or has been alive. And even the largest ordinary honeycomb consists of only a few hundred cells, while a large tree is made up of very many miillons of cells. The student must not conceive of the cell as merely a little chamber or enclosure. *The living, more or less liquid, or mucilage-like, or jelly-like substance known as protoplasm, which forms a large portion of the bulk of living and growing cells, is the all-important part of such a cell.* Professor Huxley has well called this substance "the physical basis of life." Cells are of all shapes and sizes, from little spheres a ten-thousandth of an inch or less in diameter to slender tubes, such as fibers of cotton, several inches long. To get an idea of the appearance of some rather large cells, scrape a little pulp from a ripe, mealy apple, and examine it first with

[1] The differentiation between the starch grains, the other cell-contents, and the cell-walls will appear better in the drawings if the starch grains are sketched with blue ink.

a strong magnifying glass, then with a moderate power of the compound microscope. To see how dead, dry cell-walls, with nothing inside them, look, examine (as before) a very thin slice of elder pith, sunflower pith, or pith from a dead cornstalk. Look also at the figures in Chapter VI of this book. Notice that the simplest plants (Chapter XX) consist of a single cell each. The study of the structure of plants is the study of the forms which cells and groups of cells assume, and the study of plant physiology is the study of what cells and cell combinations do.

25. Absorption of Starch from the Cotyledons. — Examine with the microscope, using a medium power, soaked beans and the cotyledons from seedlings that have been growing for three or four weeks. Stain the sections with iodine solution, and notice how completely the clusters of starch grains that filled most of the cells of the unsprouted cotyledons have disappeared from the shriveled cotyledons of the seedlings. A few grains may be left, but they have lost their sharpness of outline.

26. Oil. — The presence of oil in any considerable quantity in seeds is not as general as is the presence of starch, though in many common seeds there is a good deal of it.

Sometimes the oil is sufficiently abundant to make it worth while to extract it by pressure, as is done with flax-seed, cotton-seed, the seeds of some plants of the cress family, the "castor bean," and other seeds.

27. Dissolving Oil from Ground Seeds. — It is not possible easily to show a class how oil is extracted from seeds by pressure; but there are several liquids which readily dissolve oils and yet have no effect on starch and most of the other constituents of seeds.

EXPERIMENT IX

Extraction of Oil by Ether or Benzine. — To a few ounces of ground flaxseed add an equal volume of ether or benzine. Let it stand ten or fifteen minutes and then filter. Let the liquid stand in a saucer or evaporating dish in a good draught till it has lost the odor of the ether or benzine.

Describe the oil which you have obtained.

Of what use would it have been to the plant?

If the student wishes to do this experiment at home for himself, he should bear in mind the following:

Caution. — Never handle benzine or ether near a flame or stove.

A much simpler experiment to find oil in seeds may readily be performed by the pupil at home. Put the material to be studied, *e.g.*, flaxseed meal, corn meal, wheat flour, cotton-seed meal, buckwheat flour, oatmeal, and so on, upon little labeled pieces of white paper, one kind of flour or meal on each bit of paper. Place all the papers, with their contents, on a perfectly clean plate, free from cracks, or on a clean sheet of iron, and put this in an oven hot enough nearly (but not quite) to scorch the paper. After half an hour remove the plate from the oven, shake off the flour or meal from each paper, and note the results, a more or less distinct grease spot showing the presence of oil, or the absence of any stain that there was little or no oil in the seed examined.

28. Albuminous Substances. — Albuminous substances or *proteids* occur in all seeds, though often only in small quantities. They have nearly the same chemical composition as white of egg and the curd of milk among animal substances, and are essential to the plant, since the living and growing parts of all plants contain large quantities of proteid material.

Sometimes the albuminous constituents of the seed occur in more or less regular grains (Fig. 8, at *Kl*).

But much of the proteid material of seeds is not in any form in which it can be recognized under the microscope. One test for its presence is the peculiar smell which it produces in burning. Hair, wool, feathers, leather, and lean meat all produce a well-known sickening smell when scorched or burned, and the similarity of the proteid material in such seeds as the bean and pea to these substances is shown by the fact that scorching beans and similar seeds give off the familiar smell of burnt feathers.

29. Chemical Tests for Proteids. — All proteids (and very few other substances) are turned yellow by nitric acid, and this yellow color becomes deeper or even orange when the yellowish substance is moistened with ammonia. They are also turned yellow by iodine solution. Most proteids are turned more or less red by the solution of nitrate of mercury known as Millon's reagent.[1]

EXPERIMENT X

Detection of Proteids in Seeds. — Extract the germs from some soaked kernels of corn and bruise them; soak some wheat-germ meal for a few hours in warm water, or wash the starch out of wheat-flour dough; reserving the latter for use, place it in a white saucer or porcelain evaporating dish, and moisten well with Millon's reagent or with nitric acid; examine after fifteen minutes.

30. The Brazil-Nut as a Typical Oily Seed. — Not many familiar seeds are as oily as the Brazil-nut. Its large size makes it convenient for examination, and the fact that this nut is good for human food makes it the more interesting to investigate the kinds of plant-food which it contains.

[1] See *Handbook*.

EXPERIMENT XI

Testing Brazil-Nuts for Plant-Foods. — Crack fifteen or twenty Brazil-nuts, peel off the brown coating from the kernel of each, and then grind the kernels to a pulp in a mortar. Shake up this pulp with ether, pour upon a paper filter, and wash with ether until the washings when evaporated are nearly free from oil. The funnel containing the filter should be kept covered as much as possible until the washing is finished. Evaporate the filtrate to procure the oil, which may afterwards be kept in a glass-stoppered bottle. Dry the powder which remains on the filter and keep it in a wide-mouthed bottle. Test portions of this powder for proteids and for starch. Explain the results obtained.

31. Other Constituents of Seeds. — Besides the substances above suggested, others occur in different seeds. Some of these are of use in feeding the seedling, others are of value in protecting the seed itself from being eaten by animals or in rendering it less liable to decay. In such seeds as that of the nutmeg, the essential oil which gives it its characteristic flavor probably makes it unpalatable to animals and at the same time preserves it from decay.

Date seeds are so hard and tough that they cannot be eaten and do not readily decay. Lemon, orange, horse-chestnut and buckeye seeds are too bitter to be eaten, and the seeds of the apple, cherry, peach, and plum are somewhat bitter.

The seeds of larkspur, thorn-apple,[1] croton, the castor-oil plant, nux vomica, and many other kinds of plants contain active poisons.

[1] Datura, commonly called "Jimpson weed."

CHAPTER III

MOVEMENTS, DEVELOPMENT, AND MORPHOLOGY OF THE SEEDLING

32. How the Seedling breaks Ground. — As the student has already learned by his own observations, the seedling does not always push its way straight out of the ground. Corn, like all the other grains and grasses, it is true, sends a tightly rolled, pointed leaf vertically upward into the air. But the other seedlings examined usually will not be found to do anything of the sort. The squash seedling is a good one in which to study what may be called the arched hypocotyl type of germination. If the seed when planted is laid hori-

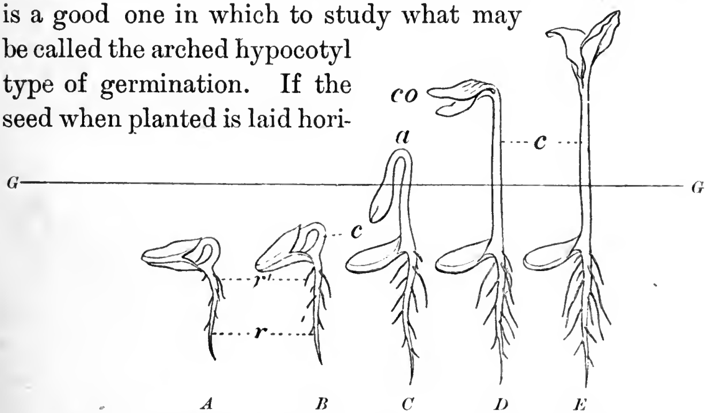


Fig. 9. — Successive Stages in the Life History of the Squash Seedling.

GG, the surface of the ground; *r*, primary root; *r′*, secondary root; *c*, hypocotyl; *a*, arch of hypocotyl; *co*, cotyledons.

zontally on one of its broad surfaces, it usually goes through some such changes of position as are shown in Fig. 9.

The seed is gradually tilted until, at the time of their emergence from the ground (at *C*), the cotyledons are almost vertical. The only part above the ground-line *G*, *G*, at this period, is the arched hypocotyl. Once out of ground, the cotyledons soon rise, until (at *E*) they are again vertical, but with the other end up from that which stood highest in *C*. Then the two cotyledons separate until they once more lie horizontal, pointing away from each other.

Can you suggest any advantage which the plant derives from having the cotyledons dragged out of the ground rather than having them pushed out, tips first?

33. Cause of the Arch. — It is evident that a flexible object like the hypocotyl, when pushed upward through the earth, might easily be bent into an arch or loop. Whether the shape which the hypocotyl assumes is wholly caused by the resistance of the soil can best be ascertained by an experiment.

EXPERIMENT XII

Is the Arch of the Hypocotyl due to the Pressure of the Soil on the Rising Cotyledons? — Sprout some squash seeds on wet paper under a bell-glass, and when the root is an inch or more long, hang several of the seedlings, roots down, in little stirrups made of soft twine, attached by beeswax and rosin mixture to the inside of the upper part of a bell-glass. Put the bell-glass on a large plate or a sheet of glass on which lies wet paper to keep the air moist. Note whether the seedlings form hypocotyl arches at all and, if so, whether the arch is more or less perfect than that formed by seedlings growing in earth, sand, or sawdust.

34. What pushes the Cotyledons up? — A very little study of any set of squash seedlings, or even of Fig. 9, is sufficient to show that the portion of the plant where roots and hypocotyl are joined neither rises nor sinks, but that the plant grows both ways from this part (a little above r' in Fig. 9, *A* and *B*). It is evident that as soon as the hypocotyl begins to lengthen much it must do one of two things: either push the cotyledons out into the air or else force the root down into the ground as one might push a stake down. What changes does the plantlet undergo, in passing from the stage shown at *A* to that of *B* and of *C*, making it harder and harder for the root to be thrust downward?

35. Use of the Peg. — Squash seedlings usually (though not always) form a sort of knob on the hypocotyl. This is known as the peg. Study a good many seedlings and try to find out what the lengthening of the hypocotyl, between the peg and the bases of the cotyledons, does for the little plant. Set a lot of squash seeds, hilum down, in moist sand or sawdust and see whether the peg is more or less developed than in seeds sprouted lying on their sides, and whether the cotyledons in the case of the vertically planted seeds usually come out of the ground in the same condition as do those shown in Fig. 9.

36. Discrimination between Root and Hypocotyl. — It is not always easy to decide by their appearance and behavior what part of the seedling is root and what part is hypocotyl. In a seedling visibly beginning to germinate, the sprout, as it is commonly called, which projects from the seed might be either root or hypocotyl or might consist of both together, so far as its appearance is concerned. A microscopic study of the cross-section of a root, compared with one of the hypocotyl, would show decided differences of structure between the two. Their mode of growth is also different, as the pupil may infer after he has tried Exp. XIV.

37. Discrimination by Staining. — For some reason, perhaps because the skin or epidermis of the young root is not so water-proof as that of the stem, the former stains more easily than the latter does.

EXPERIMENT XIII

The Permanganate Test. — Make a solution of potassium permanganate in water, by adding about four parts, by weight, of the crystallized permanganate to 100 parts of water. Drop into the solution seedlings, *e.g.*, of all the kinds that have been so far studied, each in its earliest stage of germination (that is, when the root or hypocotyl has pushed out of the seed half an inch or less), and also at one or two subsequent stages. After the seedlings have been in the solution from three to five minutes, or as soon as the roots are considerably stained, pour off (and save) the solution and rinse the plants with plenty of clear water. Sketch one specimen of each kind, coloring the brown-stained part, which is root, in some way so as to distinguish it from the unstained hypocotyl. Note particularly how much difference there is in the amount of lengthening in the several kinds of hypocotyl examined. Decide whether the peg of the squash seedling is an outgrowth of hypocotyl or of root.

38. Disposition made of the Cotyledons. — As soon as the young plants of squash, bean, and pea have reached a height of three or four inches above the ground it is easy to recognize important differences in the way in which they set out in life.

The cotyledons of the squash increase greatly in surface, acquire a green color and a generally leaf-like appearance, and, in fact, do the work of ordinary leaves. In such a case as this the appropriateness of the name *seed-leaf* is evident enough, — one recognizes at sight the fact that the cotyledons are actually the plant's first leaves. In the bean the leaf-like nature of the cotyledons is not so clear. They rise out of the ground like the squash cotyledons, but then gradually shrivel away, though they may first turn green and somewhat leaf-like for a time.

In the pea (as in the acorn, the horse-chestnut, and many other seeds) we have quite another plan, the underground type of germination. Here the thick cotyledons no longer rise above ground at all, because they are so gorged with food that they could never become leaves; but the young stem pushes rapidly up from the surface of the soil.

The development of the plumule seems to depend somewhat on that of the cotyledons. The squash seed has cotyledons which are not too thick to become useful leaves, and so the plant is in no special haste to get ready any other leaves. The plumule, therefore, cannot be found with the magnifying glass in the unsprouted seed, and is almost microscopic in size at the time when the hypocotyl begins to show outside of the seed-coats.

In the bean and pea, on the other hand, since the cotyledons cannot serve as foliage leaves, the later leaves must be pushed forward rapidly. In the bean the first pair are already well formed in the seed. In the pea they cannot be clearly made out, since the young plant forms several scales on its stem before it produces any full-sized leaves, and the embryo contains only hypocotyl, cotyledons, and a sort of knobbed plumule, well developed in point of size, representing the lower scaly part of the stem.

39. Root, Stem, and Leaf. — By the time the seedling is well out of the ground it, in most cases, possesses the three kinds of *vegetative organs*, or parts essential to growth, of ordinary flowering plants, *i.e.*, the root, stem, and leaf, or, as they are sometimes classified, root and shoot. All of these organs may multiply and increase in size as the plant grows older, and their mature structure will be studied in later chapters, but some facts concerning them can best be learned by watching their growth from the outset.

40. Young Roots grown for Examination. — Roots growing in sand or ordinary soil cling to its particles so tenaciously that they cannot easily be studied, and those grown in water have not quite the same form as soil-roots. Roots grown in damp air are best adapted for careful study.

41. Elongation of the Root. — We know that the roots of seedlings grow pretty rapidly from the fact that each day finds them reaching visibly farther down into the water or other medium in which they are planted. A sprouted Windsor bean in a vertical thistle-tube will send its root downward fast enough so that ten minutes' watching through the microscope will suffice to show growth. To find out just where the growth goes on requires a special experiment.

EXPERIMENT XIV

In what Portions of the Root does its Increase in Length take Place? — Sprout some peas on moist blotting paper in a loosely covered tumbler. When the roots are one and a half inches or more long, mark them along the whole length with little dots made with a bristle dipped in water-proof India ink, or a fine inked thread stretched on a little bow of whalebone or brass wire.

Transfer the plants to moist blotting paper under a bell-glass or an inverted battery jar and examine the roots at the end of twenty-four hours to see along what portions their length has increased; continue observations on them for several days.

42. Root-Hairs. — Barley, oats, wheat, red clover, or buckwheat seeds soaked and then sprouted on moist blotting paper afford convenient material for studying *root-hairs*. The seeds may be kept covered with a watch-glass or a clock-glass while sprouting. After they have begun to germinate well, care must be taken not to have them kept in too moist an atmosphere, or very few root-hairs will be formed. Examine with the magnifying glass those parts of the root which have these appendages.

Try to find out whether all the portions of the root are equally covered with hairs and, if not, where they are most abundant. (See also Sect. 53.)

The root-hairs in plants growing under ordinary conditions are surrounded by the moist soil and wrap themselves around microscopical particles of earth (Fig. 11). Thus they are able rapidly to absorb through their thin walls the soil-water, with whatever mineral substances it has dissolved in it.

43. The Young Stem. — The hypocotyl, or portion of the stem which lies below the cotyledons, is the earliest formed portion of the stem. Sometimes this lengthens but little; often, however, as the student knows from his own observations, the hypocotyl lengthens enough to raise the cotyledons well above ground, as in Fig. 10.

The later portions of the stem are considered to be divided into successive *nodes*, — places at which a leaf (or a scale which represents a leaf) appears; and *internodes*,—portions between the leaves.

The student should watch the growth of a seedling bean or pea and ascertain by actual measurements whether the internodes lengthen after they have once been formed, and if so, for how long a time the increase continues.

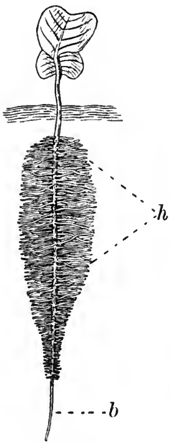


FIG. 10.

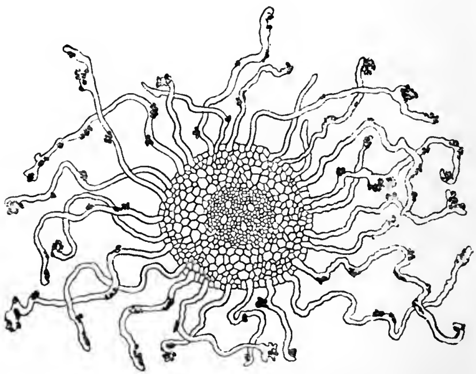


FIG. 11.

FIG. 10.—A Turnip Seedling, with the Cotyledons developed into Temporary Leaves. *h*, root-hairs from the primary root; *b*, bare portion of the root, on which no hairs have as yet been produced.

FIG. 11.—Cross-Section of a Root, a good deal magnified, showing root-hairs attached to particles of soil, and sometimes enwrapping these particles.

44. The First Leaves.—The cotyledons are, as already explained, the first leaves which the seedling possesses,—even if a plumule is found well developed in the seed, it was formed after the cotyledons. In those plants which have so much food stored in the cotyledons as to render these unfit ever to become useful foliage leaves, there is little or nothing in the color, shape, or general appearance of the cotyledon to make one think it really a leaf, and it is only by studying many cases that the botanist is enabled to class all cotyledons as leaves in their nature, even if they are quite unable to do the ordinary work of leaves. The study of the various forms which the parts or organs of a plant may assume is called *morphology;* it traces the relationship of parts which are really akin to each other, though dissimilar in appearance and often in function. In seeds which have *endosperm*, or food stored outside of the embryo, the cotyledons usually become green and leaf-like, as they do, for example, in the four-o'clock, the morning-glory, and the buckwheat; but in the seeds of the grains (which contain endosperm) a large portion of the single cotyledon remains throughout as a thickish mass buried in the seed. In a few cases, as in the pea, there are scales instead of true leaves formed on the first nodes above the cotyledons, and it is only at about the third node above that leaves of the ordinary kind appear. In the bean and some other plants which in general bear one leaf at a node along the stem, there is a pair produced at the first node above the cotyledons, and the leaves of this pair differ in shape from those which arise from the succeeding portions of the stem.

FIG. 12. — Germinating Pine. *co*, cotyledons.

45. Classification of Plants by the Number of their Cotyledons. — In the pine family the germinating seed often displays more than two cotyledons, as shown in Fig. 12; in the majority of common flowering plants the seed contains two cotyledons, while in the lilies, the rushes, the sedges, the grasses, and some other plants, there is but one cotyledon. Upon these facts is based the division of most flowering plants into two great groups: the *dicotyledonous plants*, which have two seed-leaves, and the *monocotyledonous plants*, which have one seed-leaf. Other important differences nearly always accompany the difference in number of cotyledons, as will be seen later.

46. Tabular Review of Experiments. — Make out a table containing a very brief summary of the experiments thus far performed, as follows:

Number of Experiment	Object sought	Materials and Apparatus	Operations performed	Results	Inferences

47. Review Sketches. — Make out a comparison of the early life histories of all the other seedlings studied, by arranging in parallel columns a series of drawings of each, like those of Fig. 9, but in vertical series, the youngest of each at the top, thus:

	BEAN	PEA	CORN
FIRST STAGE			
SECOND STAGE			
THIRD STAGE			
FOURTH STAGE			
FIFTH STAGE ETC.			

CHAPTER IV

ROOTS [1]

48. Origin of Roots. — The *primary root* originates from the lower end of the hypocotyl, as the student learned from his own observations on sprouting seeds. The branches of the primary root are called *secondary roots*, and the branches of these are known as *tertiary roots*. Those roots which occur on the stem or in other unusual places are known as *adventitious roots*. The roots which form so readily on cuttings of willow, southernwood, tropæolum, French marigold, geranium (pelargonium), tradescantia, and many other plants, when placed in damp earth or water, are adventitious.

49. Aerial Roots. — While the roots of most familiar plants grow in the earth and are known as *soil-roots*, there are others which are formed in the air, called *aerial roots*. They serve various purposes: in some tropical air-plants (Fig. 13) they serve to fasten the plant to the tree on which it establishes itself, as well as to take in water which drips from branches and trunks above them, so that these plants require no soil and grow in mid-air suspended from trees, which serve them merely as supports; [2] many such

[1] To the plant the root is more important than the stem. The author has, however, treated the structure of the latter more fully than that of the root, mainly because the tissues are more varied in the stem and a moderate knowledge of the more complex anatomy of the stem will serve every purpose.

[2] If it can be conveniently managed, the class will find it highly interesting and profitable to visit any greenhouse of considerable size, in which the aerial roots of orchids and aroids may be examined.

air-plants are grown in greenhouses. In such plants as the ivy (Fig. 15) the aerial roots (which are also adventitious) hold the plant to the wall or other surface up which it climbs.

In the Indian corn (Fig. 14) roots are sent out from nodes at some distance above the ground and finally descend until they enter the ground. They serve both to anchor the cornstalk so as to enable it to resist the wind and to supply additional water to the plant.[1] They often produce no rootlets until they reach the ground.

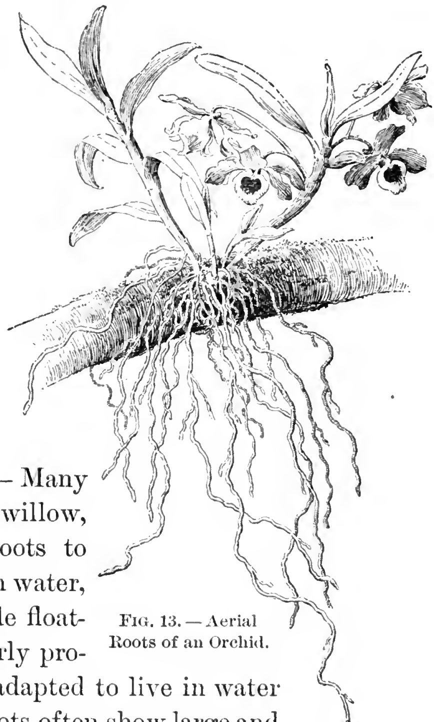


FIG. 13. — Aerial Roots of an Orchid.

50. Water-Roots. — Many plants, such as the willow, readily adapt their roots to live either in earth or in water, and some, like the little floating duckweed, regularly produce roots which are adapted to live in water only. These water-roots often show large and distinct sheaths on the ends of the roots, as, for instance, in the so-called water-hyacinth. This plant is especially interesting for laboratory cultivation from the fact that

[1] Specimens of the lower part of the cornstalk, with ordinary roots and aerial roots, should be dried and kept for class study.

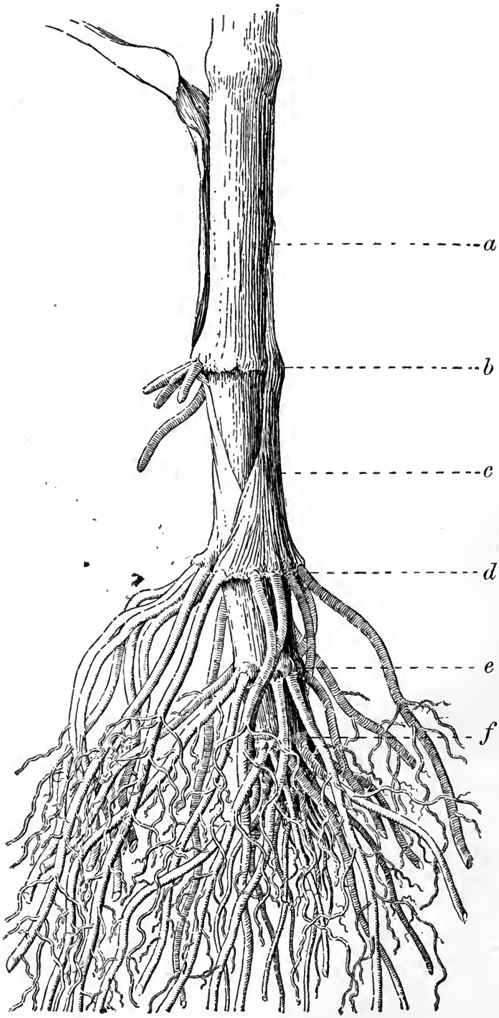


FIG. 14. — Lower Part of Stem and Roots of Indian Corn, showing Aerial Roots ("Brace-Roots").

a, *c*, internodes of the stem ; *b*, *d*, *e*, *f*, nodes of various age bearing roots. Most of these started as aerial roots, but all except those from *b* have now reached the earth.

it may readily be transferred to moderately damp soil, and that the whole plant presents curious modifications when made to grow in earth instead of water.

51. Parasitic Roots.[1] — The dodder, the mistletoe, and a good many other *parasites*, live upon nourishment which they steal from other plants, called *hosts*. The parasitic

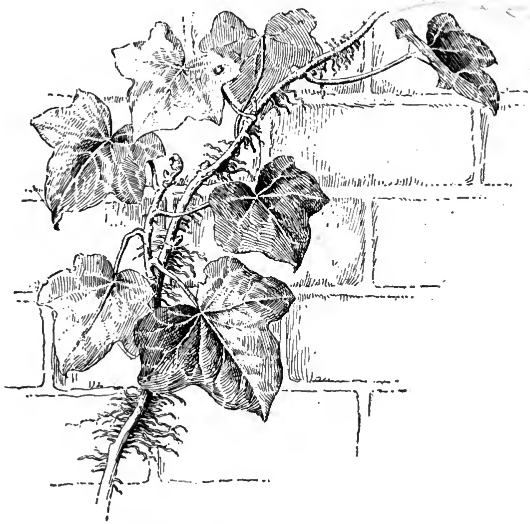


FIG. 15. — Aerial Adventitious Roots of the Ivy.

roots, or *haustoria*, form the most intimate connections with the interior portions of the stem or the root, as the case may be, of the host-plant on which the parasite fastens itself.

In the dodder, as is shown in Fig. 16, it is most interesting to notice how admirably the seedling parasite is adapted to the conditions under which it is to live. Rooted

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 171–213.

at first in the ground, it develops a slender, leafless stem, which, leaning this way and that, no sooner comes into

Fig. 16. — Dodder, growing upon a Golden-Rod Stem.

s, seedling dodder plants, growing in earth; *h*, stem of host; *r*, haustoria or parasitic roots of dodder; *l*, scale-like leaves. *A*, magnified section of a portion of willow stem, showing penetration of haustoria.

permanent contact with a congenial host than it produces haustoria at many points, gives up further growth in its soil-roots, and grows rapidly on the strength of the supplies of ready-made sap which it obtains from the host.

52. Forms of Roots. — The primary root is that which proceeds like a downward prolongation directly from the lower end of the hypocotyl. In many cases the mature root-system of the plant contains one main root much larger than any of its branches. This is called a *taproot* (Fig. 17).

Such a root, if much thickened, would assume the form

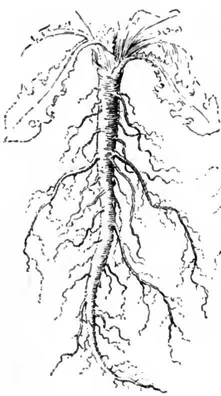


FIG. 17. — A Taproot.

FIG. 18. — Fibrous Roots.

FIG. 19. — Fascicled Roots.

shown in the carrot, parsnip, beet, turnip, salsify, or radish, and is called a fleshy root. Some plants produce *multiple primary* roots, that is, a cluster proceeding from the lower end of the hypocotyl at the outset. If such roots become thickened, like those of the sweet potato and the dahlia (Fig. 19), they are known as *fascicled roots.*

Roots of grasses, etc., are thread-like, and known as *fibrous roots* (Fig. 18).

53. General Structure of Roots. — The structure of the very young root can be partially made out by examining the entire root with a moderate magnifying power, since the whole is sufficiently translucent to allow the interior as well as the exterior portion to be studied while the root is still alive and growing.

Place some vigorous cuttings of tradescantia or *Zebrina*, which can usually be obtained of a gardener or florist, in a beaker or jar of water.[1] The jar should be as thin and transparent as possible, and it is well to get a flat-sided rather than a cylindrical one. Leave the jar of cuttings in a sunny, warm place. As soon as roots have developed at the nodes and reached the length of three-quarters of an inch or more, arrange a microscope in a horizontal position (see *Handbook*), and examine the tip and adjacent portion of one of the young roots with a power of from twelve to twenty diameters.

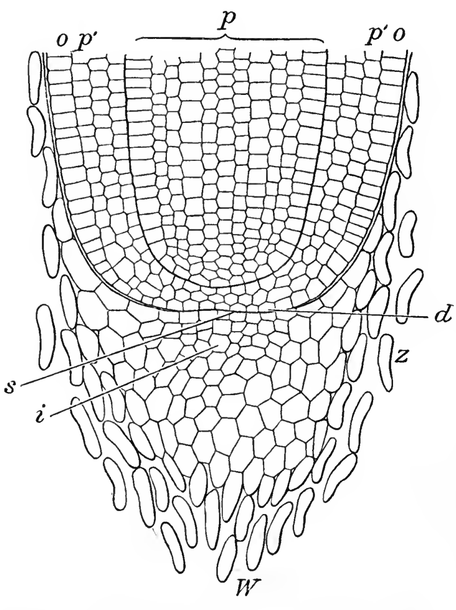


FIG. 20.—Lengthwise Section (somewhat diagrammatic) through Root-Tip of Indian Corn. × about 130.

W, root-cap; *i*, younger part of cap; *z*, dead cells separating from cap; *s*, growing point; *o*, epidermis; *p′*, intermediate layer between epidermis and central cylinder; *p*, central cylinder; *d*, layer from which the root-cap originates.

Note:

(*a*) The root-cap, of loosely attached cells.

(*b*) The central cylinder.

[1] If the tradescantia or *Zebrina* cannot be obtained, roots of seedlings of oats, wheat, or barley, or of red-clover seedlings raised in a large covered cell on a microscope slide, may be used.

(*c*) The cortical portion, a tubular part enclosing the solid central cylinder.

(*d*) The root-hairs, which cover some parts of the outer layer of the cortical portion very thickly. Observe particularly how far toward the tip of the root the root-hairs extend, and where the youngest ones are found.

Make a drawing to illustrate all the points above suggested (*a*, *b*, *c*, *d*). Compare your drawing with Fig. 20. Make a careful study of longitudinal sections through the centers of the tips of very young roots of the hyacinth or the Chinese sacred lily. Sketch one section and compare the sketch with Fig. 20.

Make a study of the roots of any of the common duckweeds, growing in nutrient solution in a jar of water under a bell-glass, and note the curious root-pockets which here take the place of root-caps.

54. Details of Root-Structure. — The plan on which the young root is built has been outlined in Sect. 53. A few further particulars are necessary to an understanding of how the root does its work. On examining Fig. 21 the cylinders of which the root is made up are easily distinguished, and the main constituent parts of each can be made out without much trouble. The epidermis-cells are seen to be somewhat brick-shaped, many of them provided with extensions into root-hairs. Inside the epidermis lie several layers of rather globular, thin-walled cells, and inside these a boundary layer between the cortical or bark portion of the root and the central cylinder. This latter region is especially marked by the presence of certain groups of cells, shown at *w* and *d* and at *b*, the two former serving as channels for air and water, the latter (and *w* also) giving toughness to the root.

Roots of shrubs and trees more than a year old will be found to have increased in thickness by the process described in Sect. 106, and a section may look quite unlike the young root-section shown in Fig. 21.

55. Examination of the Root of a Shrub or Tree. — Cut thin transverse sections of large and small roots of any hardwood tree[1] and examine them first with a low power of the microscope, as a two-inch objective, to get the general disposition of the parts, then with a higher power, as the half-inch or quarter-inch, for details. With the low power, note:

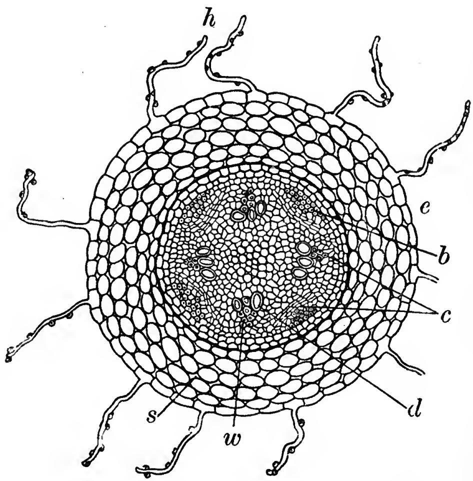


FIG. 21. — Much Magnified Cross-Section of a Very Young Dicotyledonous Root.

h, **root-hairs with adhering bits of sand ;** ***e***, **epidermis ;** ***s***, **thin-walled, nearly globular cells of bark ;** ***b***, **hard bast ;** ***c***, **cambium ;** ***w***, **wood-cells ;** ***d***, **ducts.**

(*a*) The brown layer of outer bark.

(*b*) The paler layer within this.

(*c*) The woody cylinder which forms the central portion of the root.

The distinction between (*b*) and (*c*) is more evident when the section has been exposed to the air for a few minutes and changed somewhat in color. It is a good plan to look with the low power first at a thick section, viewed as an opaque object, and then at a very thin one mounted in water or glycerine, and viewed as a transparent object.

Observe the cut-off ends of the *ducts*, or *vessels*, which serve as passages for air and water to travel through; these appear as holes in the section, and are much more abundant relatively in the young

[1] Young suckers of cherry, apple, etc., which may be pulled up by the roots, will afford excellent material.

than in the older and larger portions of the root. Sketch one section of each kind.

Examine with a higher power (100 to 200 diameters), and note the ends of the thick-walled wood-cells. Compare these with Fig. 72.

Notice the many thinner-walled cells composing stripes radiating away from the center of the root. These bands are the *medullary rays*, whose mode of origin is shown in Fig. 68. Moisten some of the sections with iodine solution,[1] and note where the blue color shows the presence of starch. Split some portions of the root through the middle, cut thin sections from the split surface, and examine with the high power some unstained and some stained with iodine.

Notice the appearance of the wood-cells and the ducts as seen in these sections, and compare with Fig. 58.[2]

56. Structure and Contents of a Fleshy Root. — In some fleshy roots, such as the beet, the morphology of the parts is rather puzzling, since they form many layers of tissue in a single season, showing on the cross-section of the root a series of layers which look a little like the annual rings of trees.

The structure of the turnip, radish, carrot, and parsnip is simpler.

Cut a parsnip across a good deal below the middle, and stand the cut end in eosin solution for twenty-four hours.

Then examine by slicing off successive portions from the upper end. Sketch some of the sections thus made. Cut one parsnip lengthwise and sketch the section obtained. In what portion of the root did the colored liquid rise most readily? The ring of red marks the boundary between the cortical portion and the central cylinder. To which does the main bulk of the parsnip belong? Cut thin transverse sections from an ink-stained parsnip and notice how the medullary rays run out into the cortical portion, and in those sections

[1] If the roots are in their winter condition.

[2] The examination of the minute structure of the root is purposely made very hasty, since the detailed study of the structural elements can be made to better advantage in the stem.

that show it, find out where the secondary roots arise. If possible, peel off the cortical portion from one stained root and leave the central cylinder with the secondary roots attached. Stain one section with iodine, and sketch it. Where is the starch of this root mainly stored?

Test some bits of parsnip for proteids, by boiling them for a minute or two with strong nitric acid.

What kind of plant-food does the taste of cooked parsnips show them to contain? [On no account taste the bits which have been boiled in the poisonous nitric acid.]

57. Storage in Other Roots. — The parsnip is by no means a remarkable plant in its capacity for root-storage. The roots of the yam and the sweet potato contain a good deal of sugar and much more starch than is found in the parsnip. Beet-roots contain so much sugar that a large part of the sugar supply of Europe and an increasing portion of our own supply is obtained from them. Oftentimes the bulk of a fleshy root is exceedingly large as compared with that of the parts of the plant above ground.

The South African plant (*Harpagophytum*, Chapter XXIV) is a good example of this, and another instance is that of a plant,[1] related to the morning-glory and the sweet potato, found in the southeastern United States, which has a root of forty or fifty pounds weight.

Not infrequently roots have a bitter or nauseous taste, as in the case of the chicory, the dandelion, and the rhubarb, and a good many, like the monkshood, the yellow jasmine, and the pinkroot, are poisonous. Can you give any reason why the plant may be benefited by the disgusting taste or poisonous nature of its roots?

[1] *Ipomœa Jalapa.*

58. Use of the Food stored in Fleshy Roots. — The parsnip, beet, carrot, and turnip are *biennial plants;* that is, they do not produce seed until the second summer or fall after they are planted.

The first season's work consists mainly in producing the food which is stored in the roots. To such storage is due their characteristic fleshy appearance. If this root is planted in the following spring, it feeds the rapidly growing stem which proceeds from the bud at its summit, and an abundant crop of flowers and seed soon follows; while the root, if examined in late summer, will be found to be withered, with its store of reserve material quite exhausted.

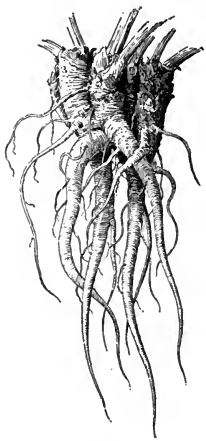


FIG. 22. — Fleshy Roots of Garden Rhubarb. (About one-fifteenth natural size.)

The roots of the rhubarb (Fig. 22), the sweet potato, and of a multitude of other *perennials*, or plants which live for many years, contain much stored plant-food. Many such plants die to the ground at the beginning of winter, and in spring make a rapid growth from the materials laid up in the roots.

59. Extent of the Root-System. — The total length of the roots of ordinary plants is much greater than is usually supposed. They are so closely packed in the earth that only a few of the roots are seen at a time during the process of transplanting, and when a plant is pulled or dug up in the ordinary way, a large part of the whole mass of roots is broken off and left behind. A few plants have been carefully studied to ascertain the total weight and length of the roots. Those of winter wheat have been found to extend to a depth of seven feet. By weighing the whole root-system of a plant and then weighing a known length of a root of average diameter, the total length of the roots may be estimated. In this way the roots of an oat plant have been calculated to measure about 154 feet; that is, all the roots, if cut off and strung together end to end, would reach that distance.

Single roots of large trees often extend horizontally to great distances, but it is not often possible readily to trace the entire depth to which they extend. One of the most notable examples of an enormously developed root-system is found in the mesquite of the far Southwest and Mexico. When this plant grows as a shrub, reaching the height, even in old age, of only two or three feet, it is because the water supply in the soil is very scanty. In such cases the roots extend down to a depth of sixty feet or more, until they reach water, and the Mexican farmers in digging wells follow these roots as guides. Where water is more plenty, the mesquite forms a good-sized tree, with much less remarkably developed roots.

60. The Absorbing Surface of Roots. — Such aerial roots as are shown in Fig. 13 are usually covered with a spongy absorbent layer, by means of which they retain large quantities of the water which trickles down them during rain-storms. This water they afterwards gradually give up to the plant. Most water-roots (not however those of tradescantia) have no special arrangement for absorbing water except through the general surface of their epidermis. But some water-roots and most soil-roots take in water mainly through the *root-hairs.* These are delicate, hair-like outgrowths from the epidermis of the root. They are, as seen in Fig. 11, thin-walled tubes, of nearly uniform diameter, closed at the outer end and opening at the inner end into the epidermis-cell from which they spring. The relation of each hair to the epidermis-cell is still better shown in Fig. 23, which represents a very young root-hair and a considerably older one.

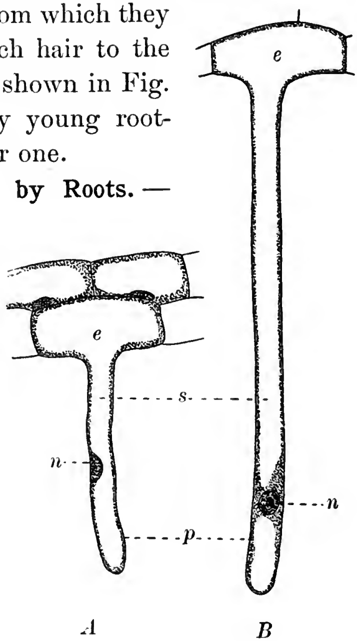


FIG. 23.

A, a very young root-hair; *B*, a much older one (both greatly magnified). *e*, cells of the epidermis of the root; *n*, nucleus; *s*, watery cell-sap; *p*, thicker protoplasm, lining the cell-wall.

61. Absorption of Water by Roots. — Many experiments on the cultivation of corn, wheat, oats, beans, peas, and other familiar plants in water have proved that some plants, at any rate, can thrive very well on ordinary lake, river, or well water, together with the food which they absorb from the air (Chapter XII). Just how much water some kinds of plants give off (and therefore absorb) per day will be discussed when the uses of the leaf are studied. For the present it is sufficient to state that even an annual plant during its lifetime absorbs through the roots very many times its own weight of water. Grasses have been known to take in their weight of water in every twenty-four hours of warm, dry weather. This absorption takes place mainly through the root-hairs, which the student has examined as they occur in the seedling plant, and which are found thickly clothing the younger and more rapidly growing parts of the roots of mature plants. Some idea of their abundance may be gathered from the fact that on a rootlet of corn grown in a damp atmosphere, and about one-seventeenth of an inch in diameter, 480 root-hairs have been counted on each hundredth of an inch of root. The walls of the root-hairs are extremely thin, and they have no holes or pores visible under even the highest power of the microscope, yet the water of the soil penetrates very rapidly to the interior of the root-hairs. The soil-water brings with it all the substances which it can dissolve from the earth about the plant; and the closeness with which the root-hairs cling to the particles of soil, as shown in Figs. 11 and 21, must cause the water which is absorbed to contain more foreign matter than underground water in general does, particularly since the roots give off enough weak acid from their surface to corrode the surface of stones which they enfold or cover.

62. Osmosis. — The process by which two liquids separated by membranes pass through the latter and mingle, as soil-water does with the liquid contents of root-hairs, is called *osmosis*.

It is readily demonstrated by experiments with thin animal or vegetable membranes.

EXPERIMENT XV

Osmosis as shown in an Egg. — Cement to the smaller end of an egg a bit of glass tubing about six inches long and about three-sixteenths of an inch inside diameter. Sealing-wax or a mixture of equal parts of beeswax and resin melted together will serve for a cement.

Chip away part of the shell from the larger end of the egg, place it in a wide-mouthed bottle or a small beaker full of water, as shown in Fig. 24, then very cautiously pierce a hole through the upper end of the eggshell by pushing a knitting-needle or wire down through the glass tube.

Watch the apparatus for some hours and note any change in the contents of the tube.[1] Explain.

The rise of liquid in the tube is evidently due to water making its way through the thin membrane which lines the eggshell, although this membrane contains no pores visible even under the microscope.

EXPERIMENT XVI

Result of placing Sugar on a Begonia Leaf. — Place a little powdered sugar on the upper surface of a thick begonia leaf under a small bell-glass. Put another portion of sugar or a bit of paper alongside the leaf. Watch for several days. Explain results. The *upper* surface of this leaf contains no pores, even of microscopic size.

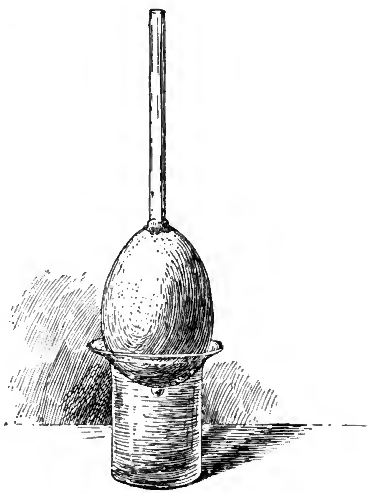


Fig. 24. — Egg on Beaker of Water, to show Osmosis.

63. Inequality of Osmotic Exchange. — The nature of the two liquids separated by any given membrane determines in which direction the greater flow shall take place.

If one of the liquids is pure water and the other

[1] Testing the contents of the beaker with nitrate of silver solution will then show the presence of more common salt than is found in ordinary water. Explain.

is water containing solid substances dissolved in it, the greater flow of liquid will be away from the pure water into the solution, and the stronger or denser the latter, the more unequal will be the flow. This principle is well illustrated by the egg-osmosis experiment. Another important principle is that substances which readily crystallize and are easily soluble, like salt or sugar, pass rapidly through membranes, while jelly-like substances, like white of egg, can hardly pass through them at all.

64. Study of Osmotic Action of Living Protoplasm; Plasmolysis. — The obvious parts of most living and growing plant-cells are a cell-wall, which is a skin or enclosure made of *cellulose*, and the living, active cell-contents or *protoplasm*. Every one is familiar with cellulose in various forms, one of the best examples being that afforded by clean cotton. It is a tough, white or colorless substance, chemically rather inactive. Protoplasm is a substance which differs greatly in its appearance and properties under different circumstances. It is of a very complex nature, so far as its chemical composition is concerned, belonging to the group of proteids and therefore containing not only the elements carbon, hydrogen, and oxygen, common to most organic substances, but nitrogen in addition. The protoplasm in a living cell often consists of several kinds of material; for instance, a rather opaque portion called the nucleus, and a more or less liquid portion lining the cell-walls and extending inward in strands to the nucleus (Fig. 126). Often, in living and active cells, the spaces left between strands and lining are filled with a watery liquid called the *cell-sap*.

The action of the protoplasm in controlling osmosis is well shown by the process known as *plasmolysis*.

Put some living threads of pond-scum (*Spirogyra*) (Chapter XX) into a 4 per cent solution of glycerine in water, a 16 per cent solution of cane sugar, or (for quick results) a 2 per cent solution of common salt.[1] Any one of these solutions is much denser than the cell-sap inside the cells of the pond-scum, and therefore the watery part of the cell-contents will be drawn out of the interior of the cell and the protoplasmic lining will collapse, receding from the cell-wall. The cell-contents are then said to be *plasmolyzed*. Sketch several cells in this condition. Remove the filaments of *Spirogyra* and place them in fresh water. How do they now behave? Explain. Repeat the plasmolyzing operation with another set of cells which have first been killed by soaking them for five minutes in a mixture of equal quantities of acetic acid, three parts to 1000 of water, and chromic acid, seven parts to 1000 of water. The pond-scum threads before being transferred from the killing solution into the plasmolyzing solution should be rinsed with a little clear water. Note how the cells now behave. How is it shown that they have lost their power of causing a liquid to be transferred mainly or wholly in one direction? Why do frozen or boiled slices of a red beet color water in which they are placed, while fresh slices do not?

65. Osmosis in Root-Hairs. — The soil-water (practically identical with ordinary spring or well water) is separated from the more or less sugary or mucilaginous sap inside of the root-hairs only by their delicate cell-walls, lined with a thin layer of protoplasm. This soil-water will pass rapidly into the plant, while very little of the sap will come out. The selective action, which causes the flow of liquid through the root-hairs to be almost wholly inward, is due to the living layer of protoplasm (Chapter XII), which covers the inner surface of the cell-wall of the root-hair. When the student has learned how active a substance protoplasm often shows itself to be, he will not be astonished to find it behaving almost as though it were

[1] This should be done as a demonstration by the teacher.

possessed of intelligence and will. Plants of two different species, both growing in the same soil, usually take from it very various amounts or kinds of mineral matter. For instance, barley plants in flower and red-clover plants in flower contain about the same proportion of mineral matter (left as ashes after burning). But the clover contains $5\frac{2}{3}$ times as much lime as the barley, and the latter contains about eighteen times as much silica as the clover. This difference must be due to the selective action of the protoplasm in the absorbing cells of the roots. Traveling by osmotic action from cell to cell, a current of water derived from the root-hairs is forced up through the roots and into the stem, just as the contents of the egg was forced up into the tube shown in Fig. 24.

66. Root-Pressure. — The force with which the upward-flowing current of water presses may be estimated by attaching a mercury gauge to the root of a tree or the stem of a small sapling. This is best done in early spring after the thawing of the ground, but before the leaves have appeared. The experiment may also be performed indoors upon almost any plant with a moderately firm stem, through which the water from the soil rises freely. A dahlia plant or a tomato plant answers well, though the root-pressure from one of these will not be nearly as great as that from a larger shrub or a tree growing out of doors. In Fig. 25 the apparatus is shown attached to the stem of a dahlia. The difference of level of the mercury in the bent tube serves to measure the root-pressure. For every foot of difference in level there must be a pressure of nearly six pounds per square inch on the stump at the base of the tube *T*.[1]

[1] See *Handbook*.

A black-birch root tested in this way at the end of April has given a root-pressure of thirty-seven pounds to the square inch. This would sustain a column of water about eighty-six feet high.

67. Root-Absorption and Temperature of Soil. — It would not be remarkable if the temperature of roots and the earth about them had something to do with the rate at which they absorb water, since this absorption depends on the living protoplasm of the root-hairs (see Sects. 64, 65). An experiment will serve to throw some light on this question.

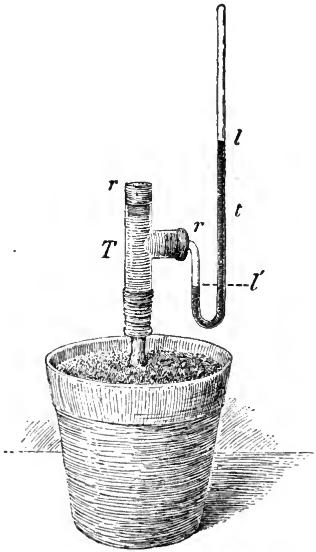


FIG. 25. — Apparatus to Measure Root-Pressure.

T, large tube fastened to the stump of the dahlia stem by a rubber tube; *r r*, rubber stoppers; *t*, bent tube containing mercury; *l l′*, upper and lower level of mercury in *T*.

EXPERIMENT XVII

Effect of Temperature on Absorption of Water by Roots. — Transplant a tobacco seedling about four inches high into rich earth contained in a narrow, tall beaker or very large test-tube (not less than $1\frac{1}{4}$ inch in diameter and six inches high). When the plant has begun to grow again freely, in a warm, sunny room, insert a chemical thermometer into the earth, best by making a hole with a sharp round stick, pushed nearly to the bottom of the tube, and then putting the thermometer in the place of the stick. Water the plant well, then set the tube in a jar of pounded ice which reaches nearly to the top of the tube. Note the temperature of the earth just before placing it in the ice. Observe whether the leaves of the seedling wilt, and, if so, at what temperature the wilting begins. Finally, remove the tube from the ice and place it in warm water (about 80°). Observe the effect and note the temperature at which the plant, if wilted, begins to revive. Find an average between the wilting temperature and the reviving temperature. For what does this average stand?

68. Movements of Young Roots. — The fact that roots usually grow downward is so familiar that we do not generally think of it as a thing that needs discussion or explanation. Since they are pretty flexible, it may seem as though young and slender roots merely hung down by their own weight, like so many bits of wet cotton twine. But a very little experimenting will answer the question whether this is really the case.

EXPERIMENT XVIII

Do all Parts of the Root of the Windsor Bean Seedling bend downward alike? — Fasten some sprouting Windsor beans with roots about an inch in length to the edges of a disk of pine wood or other soft wood in a soup-plate nearly full of water and cover them with a low bell-jar. Pins run through the cotyledons, as in Fig. 26, will hold the beans in place. When the roots have begun to point downward strongly, turn most of the beans upside down and pin them in the reversed position. If you choose, after a few days reverse them again. Make sketches of the various forms that the roots assume and discuss these.

EXPERIMENT XIX

Does the Windsor Bean Root-Tip press downward with a Force greater than its Own Weight? — Arrange a sprouted bean as shown in Fig. 26, selecting one that has a root about twice as long as the diameter of the bean and that has grown out horizontally, having been sprouted on a sheet of wet blotting paper. The bean is pinned to a cork that is fastened with beeswax and resin mixture to the side of a little trough or pan of glass or glazed earthenware. The pan is filled half an inch or more with mercury, and on top of the mercury is a layer of water. The whole is closely covered by a large tumbler or a bell-glass. Allow the apparatus to stand until the root has forced its way down into the mercury. Then run a slender needle into the root where it enters the mercury (to mark the exact level), withdraw the root, and measure the length of the part submerged in mercury. To see whether this part would have stayed under by virtue of its own weight, cut it off and lay it on the mercury. Push it under with a pair of steel forceps and then let go of it. What does it do?

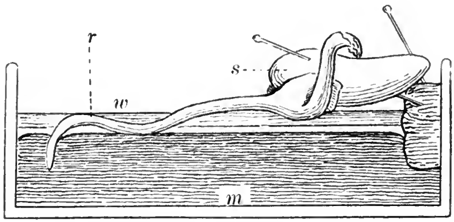


FIG. 26. — A Sprouting Windsor Bean pushing its Root-Tip into Mercury.

s, seed; *r*, root; *w*, layer of water; *m*, mercury.

69. Discussion of Exp. XIX. — By comparing the weights of equal bulks of mercury and Windsor bean roots, it is found that the mercury is about fourteen times as heavy as the substance of the roots. Evidently, then, the submerged part of the root must have been held under by a force about fourteen times its own weight. Making fine equidistant cross-marks with ink along the upper and the lower surface of a root that is about to bend downward at the tip, readily shows that those of the upper series soon come to be farther apart, — in other words, that *the root is forced to bend downward by the more rapid growth of its upper as compared with its under surface.*

70. Geotropism. — The property which plants or their organs manifest, of assuming a definite direction with reference to gravity,[1] is called *geotropism.* When, as in the case of the primary root, the effect of gravity is to make the part if unobstructed turn or move downward, we say that the geotropism is *positive.* If the tendency is to produce upward movement, we say that the geotropism is *negative;* if horizontal movement, that it is *lateral.* It was stated in the preceding section that the direct cause of the downward extension of roots is unequal growth. We might easily suppose that this unequal growth is not due to gravity, but to some other cause. To test this supposition, the simplest plan (if it could be carried out) would be to remove the plants studied to some distant region where gravity does not exist. This of course cannot be done, but we can easily turn a young seedling over and over so that gravity will act on it now in one direction, now in another, and so leave no more impression than if it did not act at all (Exp. XX). Or we can whirl a plant so fast that not only is gravity done away with, but another force is introduced in its place. If a vertical wheel, like a carriage wheel, were provided with a few loosely fitting iron rings strung on the spokes, when the wheel was revolved rapidly the rings would all fly out to the rim of the wheel. So in Fig. 27 it will be

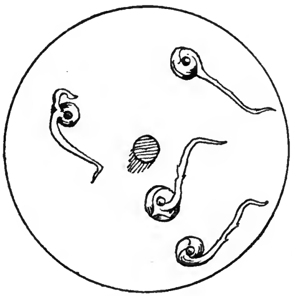


FIG. 27.—Sprouting Peas, on the Disk of a rapidly Whirling Clinostat.

The youngest portions of the roots all point directly away from the axis about which they were revolved.

[1] Gravity means the pull which the earth exerts upon all objects on or near its surface.

noticed that the growing tips of the roots of the sprouting peas point almost directly outward from the center of the disk on which the seedlings are fastened. Explain the difference between this result and that obtained in Exp. XX.

EXPERIMENT XX

How do Primary Roots point when uninfluenced by Gravity? Pin some soaked Windsor beans to a large flat cork, cover them with thoroughly moistened chopped peat-moss, and cover this with a thin glass crystallizing dish. Set the cork on edge. Prepare another cork in the same way, attach it to a clinostat, and keep it slowly revolving in a vertical position for from three to five days. Compare the directions taken by the roots on the stationary and on the revolving cork.[1]

71. Direction taken by Secondary Roots. — As the student has already noticed in the seedlings which he has studied, the branches of the primary root usually make a considerable angle with it (Fig. 2). Often they run out for long distances almost horizontally. This is especially common in the roots of forest trees, above all in cone-bearing trees, such as pines and hemlocks. This horizontal or nearly horizontal position of large secondary roots is the most advantageous arrangement to make them useful in staying or guying the stem above, to prevent it from being blown over by the wind.

72. Fitness of the Root for its Position and Work. — The distribution of material in the woody roots of trees and shrubs and their behavior in the soil show many adaptations to the conditions by which the roots are surrounded.

[1] See Ganong's *Teaching Botanist*, pp. 182–186, for complete directions. The brief statement above given is abstracted from that of Professor Ganong.

The growing tip of the root, as it pushes its way through the soil, is exposed to bruises; but these are largely warded off by the root-cap. The tip also shows a remarkable sensitiveness to contact with hard objects, so that when touched by one it swerves aside and thus finds its way downward by the easiest path. Roots with an unequal water supply on either side grow toward the moister soil. Roots are very tough, because they need to resist strong

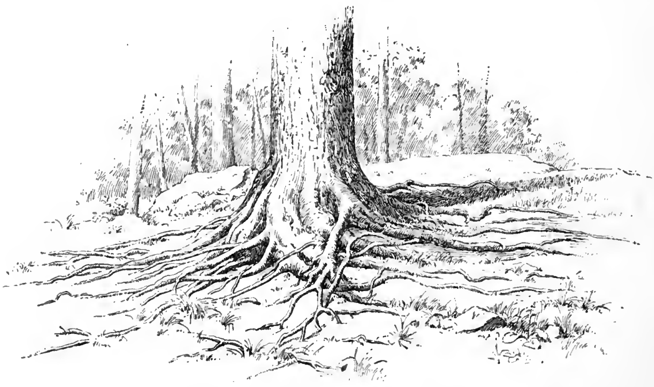


FIG. 28. — Roots of a Western Hemlock exposed by having most of the Leaf-Mould about them burned away by Forest Fires.

pulls, but not as stiff as stems and branches of the same size, because they do not need to withstand sidewise pressure, acting from one side only. The corky layer which covers the outsides of roots is remarkable for its power of preventing evaporation. It must be of use in retaining in the root the moisture which otherwise might be lost on its way from the deeper rootlets (which are buried in damp soil), through the upper portions of the root-system, about which the soil is often very dry.

73. Propagation by Means of Roots. — Some familiar plants, such as rose bushes, are usually grown from roots or root-cuttings.

Bury a sweet potato or a dahlia root in damp sand, and watch the development of sprouts from adventitious buds. One sweet potato will produce several such crops of sprouts, and every sprout may be made to grow into a new plant. It is in this way that the crop is started wherever the sweet potato is grown for the market.

74. Tabular Review of Experiments.

[Continue the table begun at end of Chapter III.]

75. Review Summary of Roots.

Kinds of roots as regards origin	
Kinds as regards medium in which they grow .	
Structure of root of a tree.	
Storage in roots	materials. location. uses.
Absorption of water by roots	apparatus. amount. proofs. causes.
Movements of roots	nature. causes. uses.

CHAPTER V

STEMS

76. What the Stem is. — The work of taking in the raw materials which the plant makes into its own food is done mainly by the roots and the leaves. These raw materials are taken from earth, from water, and from the air (see Chapter XI). The stem is that part or organ of the plant which serves to bring roots and leaves into communication with each other. In most flowering plants the stem also serves the important purpose of lifting the leaves up into the sunlight, where alone they best can do their special work.

The student has already, in Chapter III, learned something of the development of the stem and the seedling; he has now to study the external appearance and internal structure of the mature stem. Much in regard to this structure can conveniently be learned from the examination of twigs and branches of our common forest trees in their winter condition.

77. The Horse-Chestnut Twig.[1] — Procure a twig of horse-chestnut eighteen inches or more in length. Make a careful sketch of it, trying to bring out the following points:

(1) The general character of the bark.

[1] Where the buckeye is more readily obtained it will do very well. Hickory twigs answer the same purpose, and the latter is a more typical form, having alternate buds. The magnolia or the tulip tree will do. The student should (sooner or later) examine at least one opposite- and one alternate-leaved twig.

(2) The large horseshoe-shaped scars and the number and position of the dots on these scars. Compare a scar with the base of a leaf-stalk furnished by the teacher.

(3) The ring of narrow scars around the stem in one or more places,[1] and the different appearance of the bark above and below such a ring. Compare these scars with those left after removing the scales of a terminal bud and then see Fig. 29, *b sc.*

(4) The buds at the upper margin of each leaf-scar and the strong terminal bud at the end of the twig.

(5) The flower-bud scar, a concave impression, to be found in the angle produced by the forking of two twigs, which form, with the branch from which they spring, a Y-shaped figure (see Fig. 36).

(6) (On a branch larger than the twig handed round for individual study) the place of origin of the twigs on the branch; — make a separate sketch of this.

The portion of stem which originally bore any pair of leaves is called a *node*, and the portions of stem between nodes are called *internodes.*

Describe briefly in writing alongside the sketches any observed facts which the drawings do not show.

If your twig was a crooked, rough-barked, and slow-growing one, exchange it for a smooth, vigorous one, and note the differences. Or if you sketched a quickly grown shoot, exchange for one of the other kind.

FIG. 29. — A quickly grown Twig of Cherry, with Lateral and Terminal Buds in October.

b sc, bud-scale scars. All above these scars is the growth of the spring and summer of the same year.

Answer the following questions :

(*a*) How many inches did your twig grow during the last summer?

How many in the summer before?

How do you know?

How many years old is the whole twig given you?

(*b*) How were the leaves arranged on the twig?

[1] A very vigorous shoot may not show any such ring.

How many leaves were there?

Were they all of the same size?

(*c*) What has the mode of branching to do with the arrangement of the leaves? with the flower-bud scars?

(*d*) The dots on the leaf-scars mark the position of the bundles of ducts and wood-cells which run from the wood of the branch through the leaf-stalk up into the leaf.

78. Twig of Beech. — Sketch a vigorous young twig of beech (or of hickory, magnolia, tulip tree) in its winter condition, noting particularly the respects in which it differs from the horse-chestnut. Describe in writing any facts not shown in the sketch. Notice that the buds are not opposite, nor is the next one above any given bud found directly above it, but part way round the stem from the position of the first one. Ascertain, by studying several twigs and counting around, which bud is above the first and how many turns round the stem are made in passing from the first to the one directly above it.

Observe with especial care the difference between the beech and the horse-chestnut in mode of branching, as shown in a large branch provided for the study of this feature.

79. Relation of Leaf-Arrangement to Branching.[1] — This difference, referred to in Sect. 78, depends on the fact that the leaves of the horse-chestnut were arranged in pairs, on opposite sides of the stem, while those of the beech were not in pairs. Since the buds are found at the upper edges of the leaf-scars, and since most of the buds of the horse-chestnut and the beech are leaf-buds and destined to form branches, the mode of branching and ultimately the form

[1] The teacher in the Eastern and Middle States will do well to make constant use, in the study of branches and buds, of Miss Newell's *Outlines of Lessons in Botany*, Part I. The student can observe for himself, with a little guidance from the teacher, most of the points which Miss Newell suggests. If the supply of material is abundant, the twigs employed in the lessons above described need not be used further, but if material is scanty, the study of buds may at once be taken up. (See also Bailey's *Lessons with Plants*, Part I.)

of the tree must depend largely on the arrangement of leaves along the stem.

80. Opposite Branching. — In trees the leaves and buds of which are opposite, the tendency will be to form twigs in four rows about at right angles to each other along the sides of the branch, as shown in Fig. 30.

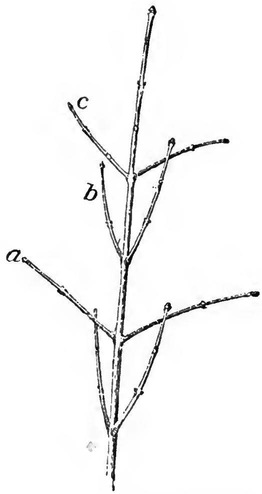


FIG. 30. — Opposite Branching in a very Young Sapling of Ash.

This arrangement will not usually be perfectly carried out, since some of the buds may never grow, or some may grow much faster than others and so make the plan of branching less evident than it would be if all grew alike.

FIG. 31. — Alternate Branching in a very Young Apple Tree.

81. Alternate Branching. — In trees like the beech the twigs will be found to be arranged in a more or less regular spiral line about the branch. This, which is known as the *alternate* arrangement (Fig. 31), is more commonly met with in trees and shrubs than the *opposite* arrangement. It admits of many varieties, since the spiral may wind more or less rapidly round the stem. In the apple, pear, cherry, poplar, oak, and walnut, one passes over five spaces before coming to a leaf which is over the first, and in doing this it is necessary to make two complete turns round the stem (Fig. 105).

82. Growth of the Terminal Bud. — In some trees the terminal bud from the very outset keeps the leading place, and the result of this mode of growth is to produce a slender, upright tree, with an *excurrent* trunk like that of Fig. 32.

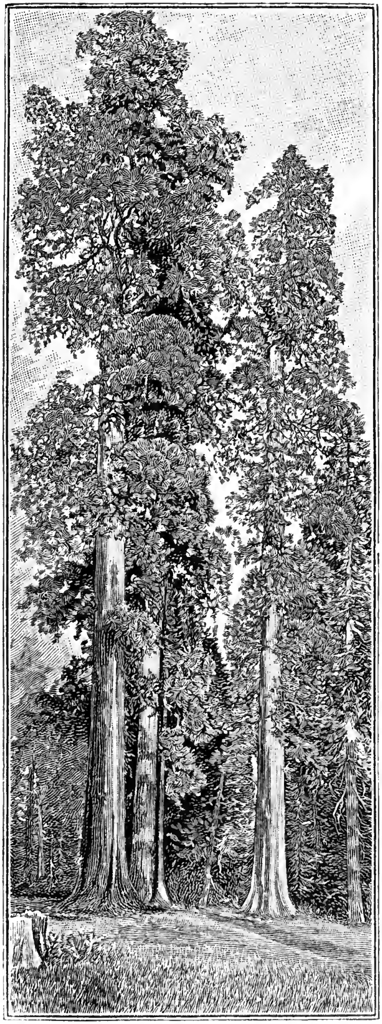


FIG. 32. — Excurrent Trunks of Big Trees (*Sequoias*).

In such trees as the apple and many oaks the terminal bud has no preeminence over others, and the form of the tree is round-topped and spreading, *deliquescent* like that in Fig. 33.

Most of the larger forest trees are intermediate between these extremes.

Branches get their characteristics to a

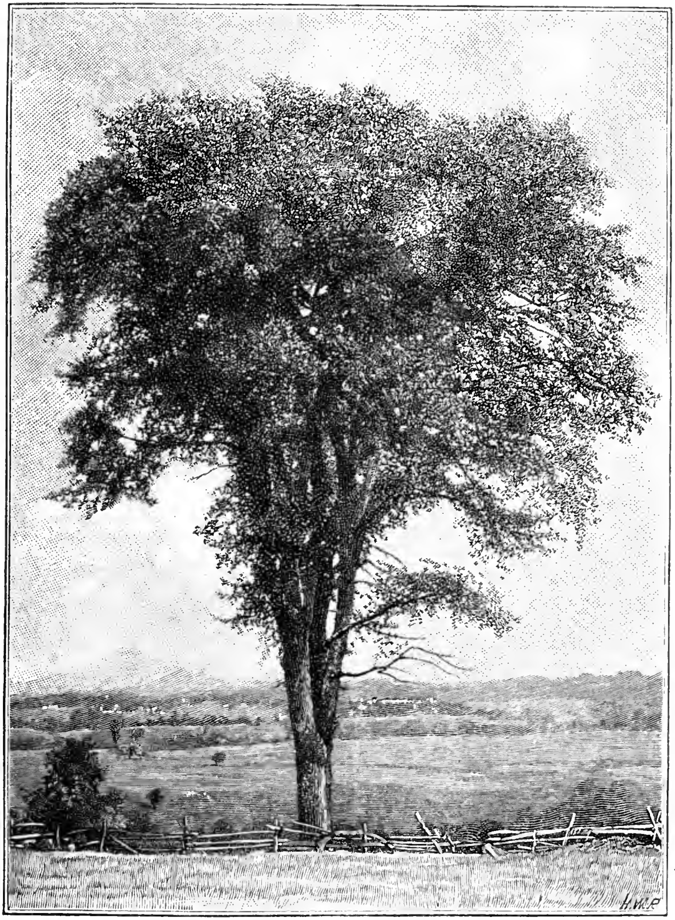


FIG. 33.—An American Elm, with Deliquescent Trunk.

considerable degree from the relative importance of their terminal buds. If these are mainly flower-buds, as is the case in the horse-chestnut and some magnolias (Figs. 35, 36), the tree is characterized by frequent forking, and has no long horizontal branches.

If the terminal bud keeps the lead of the lateral ones, but the latter are numerous and most of them grow into slender twigs, the delicate spray of the elm and many birches is produced (Fig. 37).

The general effect of the branching depends much upon the angle which each branch or twig forms with that one from which it springs. The angle may be quite acute, as in the birch; or more nearly a right angle, as in the ash (Fig. 30). The inclination of lateral branches is due to geotropism, just as is that of the branches of primary roots. The vertically upward direction of the shoot which grows from the terminal bud is also due to geotropism.

This is really only a brief way of saying that the growing tip of the main stem of the tree or of any branch is made to take and keep its proper direction, whether vertically upward or at whatever angle is desirable for the tree, by the steering action of gravity. After growth has ceased this steering action can no longer be exerted, and so a tree that has been bent over (as, for instance, by a heavy load of snow) cannot right itself, unless it is elastic enough to spring back when the load is removed. The tip of the trunk and of each branch can grow and thus become vertical, but the old wood cannot do so.

83. Thorns as Branches. — In many trees some branches show a tendency to remain dwarfish and incompletely developed. Such imperfect branches forming thorns are familiar in wild crab-apple trees and in the pear trees which occur in old pastures in the Northeastern States. In the honey locust very formidable branching spines spring from adventitious or dormant buds on the trunk or limbs. Such spines sometimes show their true nature as branches by bearing leaves (Fig. 34).

84. Indefinite Annual Growth. — In most of the forest trees, and in the larger shrubs, the wood of young branches is matured and fully developed during the summer. Protected buds are formed on the twigs of these branches to their very tips. In other shrubs — for example, in the sumac, the raspberry, and blackberry — the shoots continue to grow until their soft and immature tips are killed by the frost. Such a mode of growth is called *indefinite annual growth*, to distinguish it from the *definite annual growth* of most trees.

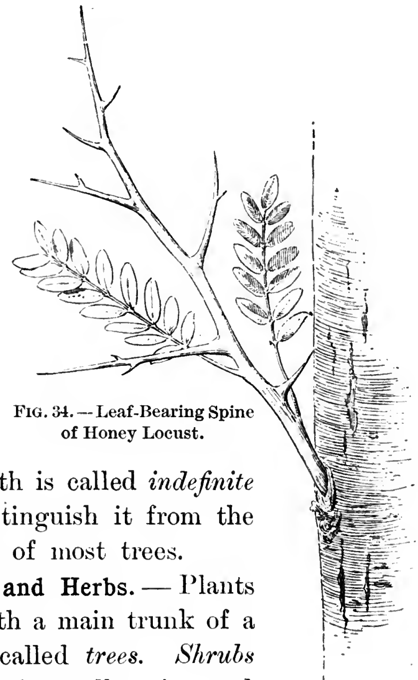


FIG. 34. — Leaf-Bearing Spine of Honey Locust.

85. Trees, Shrubs, and Herbs. — Plants of the largest size with a main trunk of a woody structure are called *trees*. *Shrubs* differ from trees in their smaller size, and generally in having several stems which proceed from the ground or near it or in having much-forked stems. The witch-hazel, the dogwoods, and the alders, for instance, are most of them classed as shrubs for this reason, though in height some of them equal the smaller trees. Some of the smallest shrubby plants, like the dwarf blueberry, the wintergreen, and the trailing arbutus, are only a few inches

Fig. 35. — **Tip of a Branch of Magnolia, illustrating Forking due to Terminal Flower-Buds.**

A, oldest flower-bud scar; *B*, *C*, *D*, scars of successive seasons after *A*; *L*, leaf-buds; *F*, flower-buds.

in height, but are ranked as shrubs because their woody stems do not die quite to the ground in winter.

Herbs are plants whose stems above ground die every winter.

86. Annual, Biennial, and Perennial Plants. — *Annual* plants are those which live but one year, *biennials* those which live two years or nearly so.

Some annual plants may be made to live over winter, flowering in their second summer. This is true of winter wheat and rye among cultivated plants.

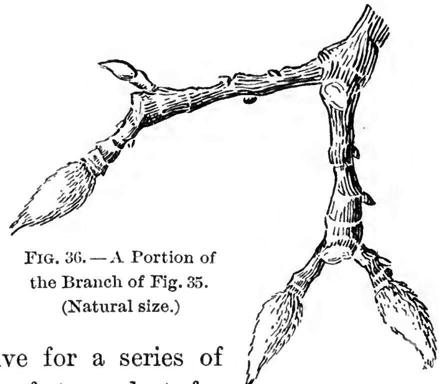


Fig. 36. — A Portion of the Branch of Fig. 35. (Natural size.)

Perennial plants live for a series of years. Many kinds of trees last for centuries. The Californian giant redwoods, or *Sequoias* (Fig. 32), which reach a height of over 300 feet under favorable circumstances, live nearly 2000 years; and some monstrous cypress trees found in Mexico were thought by Professor Asa Gray to be from 4000 to 5000 years old.

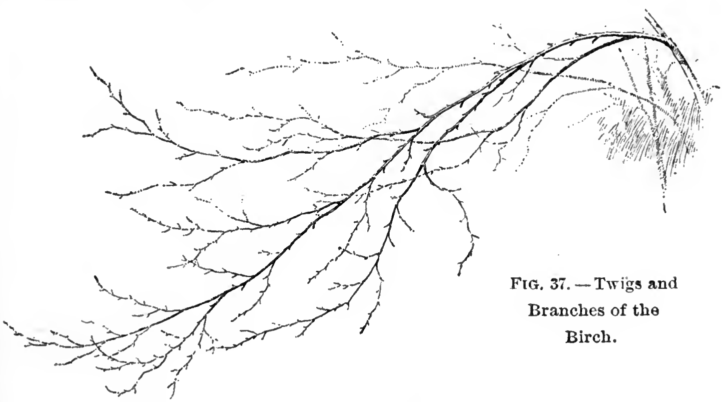


Fig. 37. — Twigs and Branches of the Birch.

87. Stemless Plants. — As will be shown later (Chapter XXX), plants live subject to a very fierce competition among themselves and exposed to almost constant attacks from animals.

While plants with long stems find it to their advantage to reach up as far as possible into the sunlight, the cinquefoil, the white clover, the dandelion, some spurges, the knot-grass, and hundreds of other kinds of plants have found safety in hugging the ground.

FIG. 38. — The Dandelion ; a so-called Stemless Plant.

Any plant which can grow in safety under the very feet of grazing animals will be especially likely to make its way in the world, since there are many places where it can flourish while ordinary plants would be destroyed. The bitter, stemless dandelion, which is almost uneatable for most animals, unless cooked, which lies too near the earth to be fed upon by grazing animals, and which bears being trodden on with impunity, is a type of a large class of hardy weeds.

The so-called *stemless plants*, like the dandelion (Fig. 38), and some violets, are not really stemless at all, but send out their leaves and flowers from a very short stem, which hardly rises above the surface of the ground.

88. Climbing and Twining Stems.[1] — Since it is essential to the health and rapid growth of most plants that they should have free access to the sun and air, it is not strange that many should resort to special devices for lifting themselves above their neighbors. In tropical forests, where the darkness of the shade anywhere beneath the tree-tops is so great that few flowering plants can thrive in it, the climbing plants or *lianas* often run like great cables for hundreds of feet before they can emerge into the sunshine above. In temperate climates no such remarkable climbers are found, but many plants raise themselves for considerable distances. The principal means to which they resort for this purpose are :

FIG. 39. — Lianas strangling a Palm.

(1) Producing roots at many points along the stem above ground and climbing on suitable objects by means of these, as in the English ivy (Fig. 15).

(2) Laying hold of objects by means of tendrils or *twining branches* or *leaf-stalks*, as shown in Figs. 40, 41.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, p. 669.

(3) Twining about any slender upright support, as shown in Fig. 42.

89. Tendril-Climbers. — The plants which climb by means of tendrils are important subjects for study, but they cannot usually be managed very well in the school-room. Continued observation soon shows that the tips of tendrils sweep slowly about in the air until they come in contact with some object about which they can coil themselves. After the tendril has taken a few turns about its support, the free part of the tendril coils into a spiral and thus draws the whole stem toward the point of attachment, as shown in Fig. 40. Some tendrils are modified leaves or stipules, as shown in Fig. 104; others are modified stems.


FIG 40. — Coiling of a Tendril of Bryony.

90. Twiners. — Only a few of the upper internodes of the stem of a twiner are concerned in producing the movements of the tip of the stem. This is kept revolving in an elliptical or circular path until it encounters some roughish and not too stout object, about which it then proceeds to coil itself.

The movements of the younger internodes of the stems of twiners are among the most extensive of all the movements made by plants. A hop-vine which has climbed to the top of its stake may sweep its tip continually around the circumference of a circle two feet in diameter, and the common wax-plant of the greenhouses sometimes describes a five-foot circle, the tip moving at the rate of thirty-two inches per hour.[1] This circular motion results from some cause not yet fully understood by botanists.[2]

The direction in which twiners coil about a supporting object is almost always the same for each species of plant, but not the same for all species. In the hop it is as shown in Fig. 42. Is it the same as in the bean? in the morning-glory?

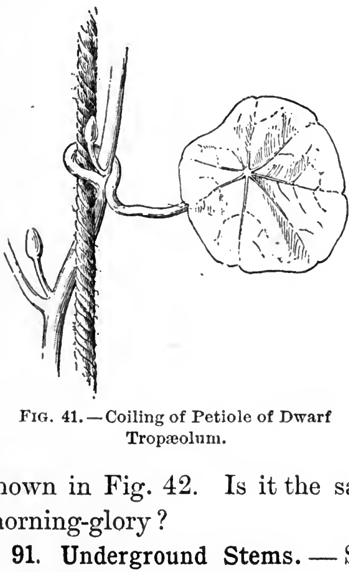


FIG. 41. — Coiling of Petiole of Dwarf Tropæolum.

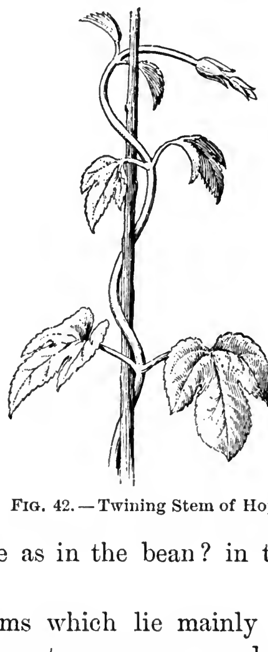


FIG. 42. — Twining Stem of Hop.

91. Underground Stems. — Stems which lie mainly or wholly underground are of frequent occurrence and of many kinds.

In the simplest form of *rootstock* (Fig. 43), such as is

[1] See article on *Climbing Plants*, by Dr. W. J. Beal, in the *American Naturalist*, Vol. IV, pp. 405–415.

[2] See Strasburger, Noll, Schenk, and Schimper, *Text-Book*, pp. 258–262; also Vines, *Students' Text-Book of Botany*, London and New York, 1894, pp. 759, 760.

found in some mints and in many grasses and sedges, the real nature of the creeping underground stem is shown by the presence upon its surface of many scales, which are reduced leaves. Rootstocks of this sort often extend horizontally for long distances in the case of grasses like the sea rye grass (Plate I), which roots itself firmly and thrives in shifting sand-dunes. In the stouter rootstocks, like that of the iris (Fig. 44) and the Caladium (Fig. 45), this stem-like character is less evident. The potato is an excellent example of the short and much-thickened underground stem known as a *tuber*.

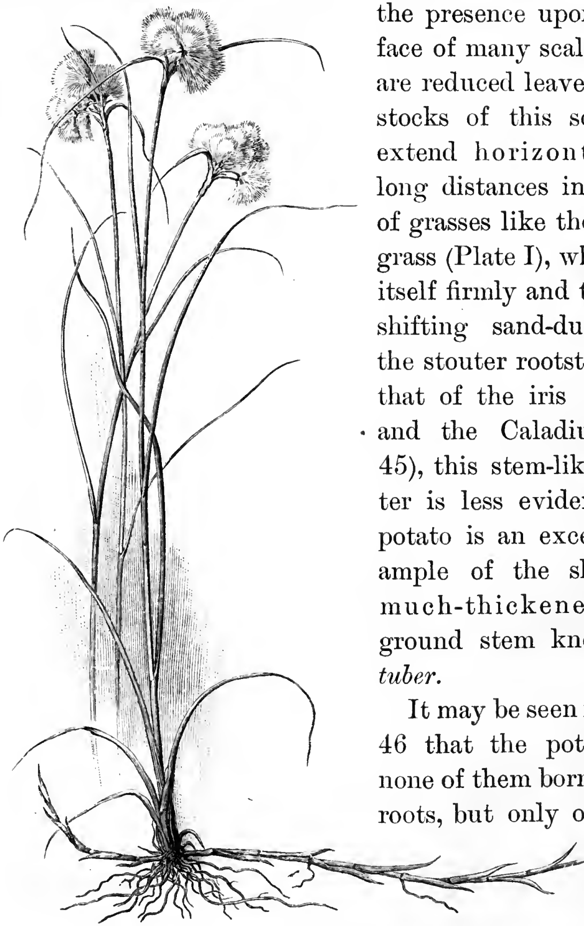


FIG. 43.—Rootstock of Cotton-Grass (*Eriophorum*).

It may be seen from Fig. 46 that the potatoes are none of them borne on true roots, but only on subterranean branches, which are stouter and more cylindrical than most of the roots. The "eyes"

Plate I. — A Sand-Loving Plant, Sea Rye Grass

which they bear are rudimentary leaves and buds.

Bulbs, whether coated like those of the onion or the hyacinth (Fig. 47), or scaly like those of the lily, are merely very short and stout underground stems, covered with closely crowded scales or layers which represent leaves or the bases of leaves (Fig. 48).

The variously modified forms of underground stems just discussed, illus-

FIG. 44.—Roots, Rootstocks, and Leaves of Iris.

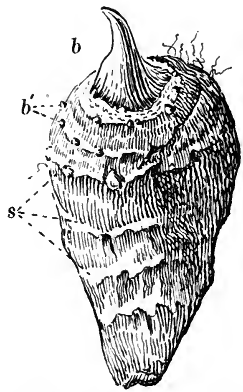


FIG. 45.—Rootstock of Caladium (*Colocasia*).

b, terminal bud; *b'*, buds arranged in circles where bases of leaves were attached; *s*, scars left by sheathing bases of leaves.

trate in a marked way the storage of nourishment during the winter (or the rainless season, as the case may be) to secure rapid growth during the active season. It is interesting to notice that nearly all of the early-flowering herbs in temperate climates, like the crocus, the snowdrop, the spring-beauty, the tulip, and the skunk-cabbage, owe their early-blooming habit to richly stored underground stems of some kind, or to thick, fleshy roots.

92. Condensed Stems. — The plants of desert regions require, above all, protection from the extreme dryness of the surrounding air, and, usually, from the excessive heat of the sun. Accordingly, many desert plants are found quite destitute of ordinary foliage, exposing to the air only a small surface. In the melon-cactuses (Fig. 49) the stem appears reduced to the shape in which the least possible surface is presented by a plant of given bulk, — that is, in a globular form. Other cactuses are more or less cylindrical or prismatic, while still others consist of flattened joints; but all agree in offering much less area to the sun and air than is exposed by an ordinary leafy plant.

Fig. 46. — Part of a Potato Plant.
The dark tuber in the middle is the one from which the plant has grown.

93. Leaf-Like Stems.—The flattened stems of some kinds of cactus (especially the common, showy *Phyllocactus*) are sufficiently like fleshy leaves, with their dark green color and imitation of a midrib, to pass for leaves. There are, however, a good many cases in which the stem takes on a more strikingly leaf-like form. The common asparagus sends up in spring shoots that bear large scales which are really reduced leaves. Later in the season, what seem like thread-like leaves cover the much-branched mature plant, but these green threads are actually minute branches, which perform the work of leaves (Fig. 50). The familiar greenhouse climber, wrongly known as smilax (properly called *Myrsiphyllum*), bears a profusion of what appear to be delicate green leaves (Fig. 51). Close study, however, shows that these are really short, flattened branches, and that each little branch springs from the axil of a true leaf, *l*, in the form of a minute scale. Sometimes a flower and a leaf-like branch spring from the axil of the same scale.

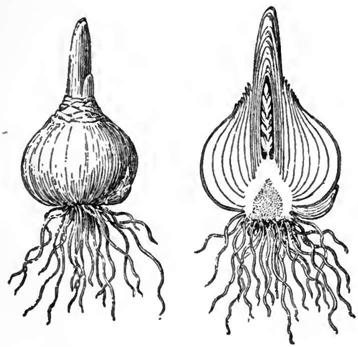


FIG. 47. — Bulb of Hyacinth. (Exterior view and split lengthwise.)

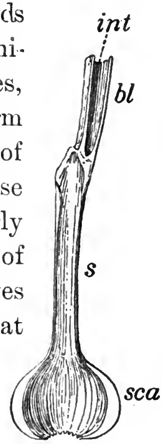


FIG. 48. — Longitudinal Section of an Onion Leaf.

sca, thickened base of leaf, forming a bulb-scale; *s*, thin sheath of leaf; *bl*, blade of the leaf; *int*, hollow interior of blade.

Branches which, like those of *Myrsiphyllum*, so closely resemble leaves as to be almost indistinguishable from them are called *cladophylls*.

94. Modifiability of the Stem. — The stem may, as in the tallest trees, in the great lianas of South American forests,

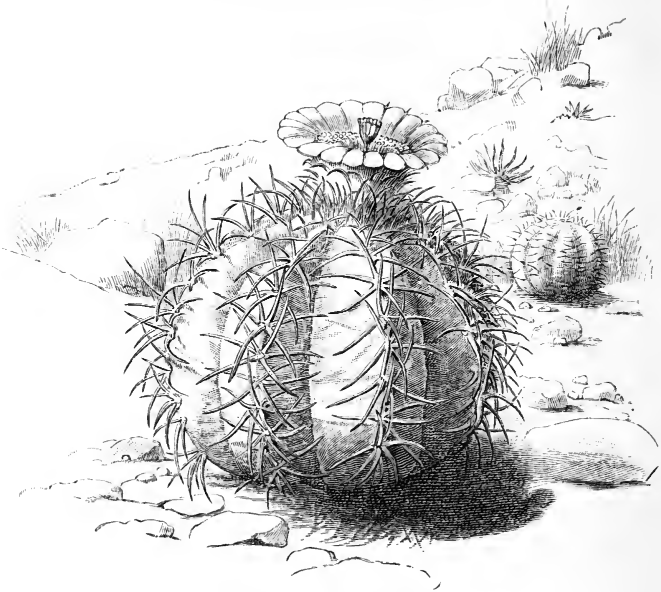


FIG. 49. — A Melon-Cactus.

FIG. 50. — A Spray of a Common Asparagus (not the edible species).

or the rattan of Indian jungles, reach a length of many hundred feet. On the other hand, in such "stemless" plants as the primrose and the dandelion, the stem may be reduced to a fraction of an inch in length. It may take

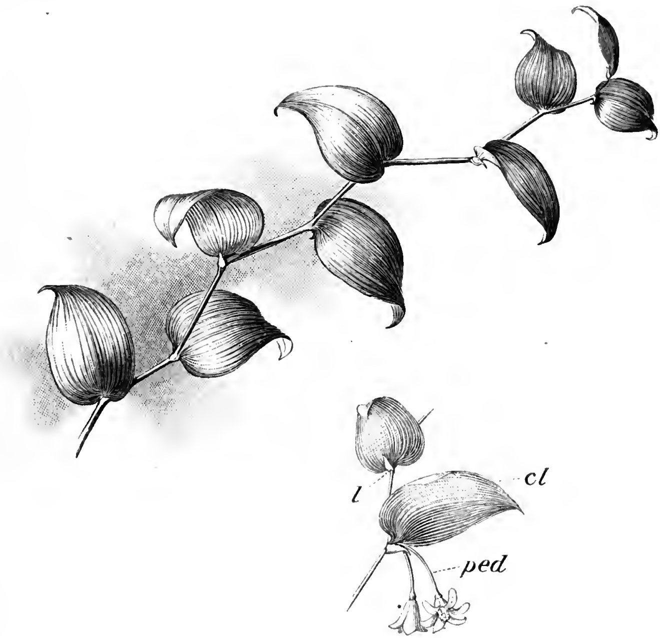


FIG. 51.—Stem of "Smilax" (*Myrsiphyllum*).
l, scale-like leaves; *cl*, cladophyll, or leaf-like branch, growing in the axil of the leaf; *ped*, flower-stalk, growing in the axil of a leaf.

on apparently root-like forms, as in many grasses and sedges, or become thickened by underground deposits of starch and other plant-food, as in the iris, the potato, and the crocus. Condensed forms of stem may exist above ground, or, on the other hand, branches may be flat and thin enough closely to imitate leaves. In short, the stem manifests great readiness in adapting itself to the most varied conditions of existence.

95. Review Summary of Stems.[1]

Kinds of branching due to leaf arrangement	1. 2.
Kinds of tree-trunk due to greater or less predominance of terminal bud	1 2.
Classes of plants based on amount of woody stem . .	1. 2. 3.
Classes of plants based on duration of life	1. 2. 3.
Various modes of climbing	1. 2. 3.
Kinds of underground stem	1. 2. 3.
Condensed stems above ground	
Leaf-like stems	

[1] Where it is possible to do so, make sketches; where this is not possible, give examples of plants to illustrate the various kinds or classes of plants in the summary.

CHAPTER VI

STRUCTURE OF THE STEM

STEM OF MONOCOTYLEDONOUS PLANTS

96. Gross Structure. — Refer back to the sketches of the corn-seedling, to recall something of the early history of the corn-stem. Study the external appearance of a piece of corn-stem or bamboo two feet or more in length. Note the character of the outer surface. Sketch the whole piece and label the enlarged *nodes* and the nearly cylindrical *internodes*. Cut across a corn-stem and examine the cut surface with the magnifying glass. Make some sections as thin as they can be cut and examine with the magnifying glass (holding them up to the light) or with a dissecting microscope. Note the firm rind, composed of the epidermis and underlying tissue, the large mass of pith composing the main bulk of the stem, and the many little harder and more opaque spots, which are the cut-off ends of the woody threads known as *fibro-vascular bundles* (Fig. 52).

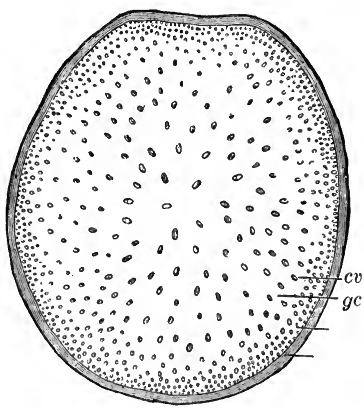


FIG. 52. — Diagrammatic Cross-Section of Stem of Indian Corn.

cv, fibro-vascular bundles; *gc*, pithy material between bundles.

Split a portion of the stem lengthwise into thin translucent slices and notice whether the bundles seem to run straight up and down its length; sketch the entire section × 2. Every fibro-vascular bundle of the stem passes outward through some node in order to connect with some fibro-vascular bundle of a leaf. This fact being known to the student would lead him to expect to find the bundles bending out of a vertical position more at the nodes than elsewhere. Can this be seen in the stem examined?

Observe the enlargement and thickening at the nodes, and split one of these lengthwise to show the tissue within it.

Compare with the corn-stem a piece of palmetto and a piece of cat-brier (*Smilax rotundifolia*, *S. hispida*, etc.), and notice the similarity of structure, except for the fact that the tissue in the palmetto and the cat-brier which answers to the pith of the corn-stem is much darker colored and harder than corn-stem pith. Compare also a piece of rattan and of bamboo.

97. Minute Structure. — Cut a thin cross-section of the corn-stem, examine with a low power of the microscope, and note:

(*a*) The rind (not true bark), composed largely of hard, thick-walled dead cells, known as *sclerenchyma* fibers.

(*b*) The fibro-vascular bundles. Where are they most abundant? least abundant?

(*c*) The pith, occupying the intervals between the fibro-vascular bundles.

Study the bundles in various portions of the section and notice particularly whether some are more porous than others. Explain. Sketch some of the outer and some of the inner ones.

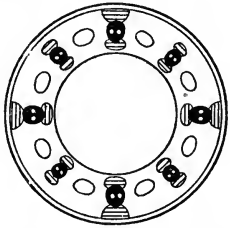


FIG. 53. — Diagrammatic Cross-Section of Stem of Bulrush (*Scirpus*), a Hollow Cylinder with Strengthening Fibers.

A more complicated kind of monocotyledonous stem-structure can be studied to advantage in the surgeons' splints cut from yucca-stems and sold by dealers in surgical supplies.

98. Mechanical Function of the Manner of Distribution of Material in Monocotyledonous Stems. — The well-known strength and lightness of the straw of our smaller grains and of rods of cane or bamboo are due to their form. It can readily be shown by experiment that an iron or steel tube of moderate thickness, like a piece of gas-pipe, or of bicycle-tubing, is much stiffer than a solid rod of the same weight per foot. The oat straw, the stems of bulrushes (Fig. 53), the cane (of our southern canebrakes), and the bamboo are hollow cylinders; the cornstalk is a solid cylinder, but filled with a very light pith. The flinty outer layer of the stalk, together with the closely packed sclerenchyma fibers of the outer rind and the frequent fibro-vascular bundles just within this, are arranged in the best way to secure stiffness. In a general way, then, we may say that the pith, the bundles, and the sclerenchymatous rind are what they are and where they are to serve important mechanical purposes. But they have other uses fully as important (Fig. 78).

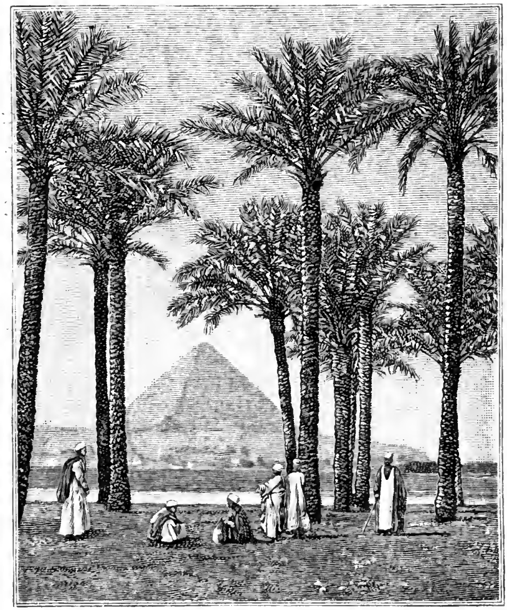


FIG. 54. — Group of Date-Palms.

99. Growth of Monocotyledonous Stems in Thickness. — In most woody monocotyledonous stems, for a reason which will be explained later in this chapter, the increase in thickness is strictly limited. Such stems, therefore, as in many palms (Fig. 54) and in rattans, are less conical and more cylindrical than the trunks of ordinary trees and are also more slender in proportion to their height.

STEM OF DICOTYLEDONOUS PLANTS

100. Gross Structure of an Annual Dicotyledonous Stem. — Study the external appearance of a piece of sunflower-stem several inches long. If it shows distinct nodes, sketch it. Examine the cross-section and sketch it as seen with the magnifying glass or the dissecting microscope. *After your sketch is finished*, compare it with Fig. 55, which probably shows more details than your drawing, and label the parts shown as they are labeled in that figure. Split a short piece of the stem lengthwise through the center and study the split surface with the magnifying glass. Take a sharp knife or a scalpel and carefully slice and then scrape away the bark until you come to the outer surface of a bundle.

Examine a vegetable sponge (*Luffa*), sold by druggists, and notice that it is simply a network of fibro-vascular bundles. It is the skeleton of a tropical seed-vessel or fruit, very much like that of the wild cucumber, common in the Central States, but a great deal larger.

The different layers of the bark cannot all be well recognized in the examination of a single kind of stem. Examine (*a*) the *cork* which constitutes the outer layers of the bark of cherry or birch branches two or more years old. Sketch the roundish or oval spongy *lenticels* on the outer surface of the bark. How far in do they extend? Examine (*b*) the *green layer* of bark as shown in twigs or branches of Forsythia, cherry, alder, box-elder, wahoo, or willow. Examine (*c*) the white, fibrous inner layer, known as *hard bast*, of the bark of elm, leatherwood, pawpaw, or basswood.

101. Minute Structure of the Dicotyledonous Stem. — Study, first with a low and then with a medium power of the compound microscope, thin cross-sections of clematis-stem cut just before the end of the first season's growth.[1] Sketch the whole section without much detail, and then make a detailed drawing of a sector running from center to circumference and just wide enough to include one of the large bundles. Label these drawings in general like Figs. 55, 56.

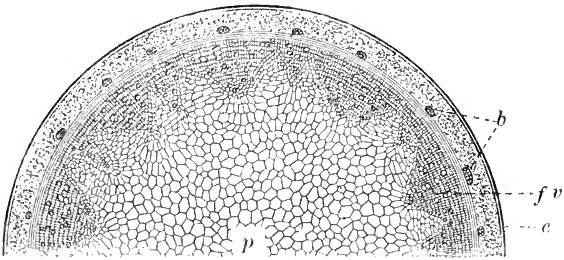


FIG. 55.— Diagrammatic Cross-Section of an Annual Dicotyledonous Stem. (Somewhat magnified.)

p, pith; *fv*, woody or fibro-vascular bundles; *e*, epidermis; *b*, bundles of hard bast fibers of the bark.

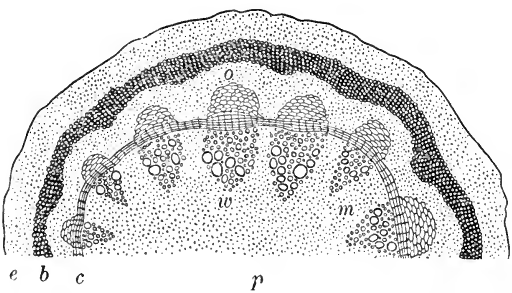


FIG. 56. — Diagrammatic Cross-Section of One-Year-Old *Aristolochia* Stem. (Considerably magnified.)

e, region of epidermis; *b*, hard bast; *o*, outer or bark part of a bundle (the cellular portion under the letter); *w*, inner or woody part of bundle; *c*, cambium layer; *p*, region of pith; *m*, a medullary ray.

The space between the hard bast and the bundles is occupied by thin-walled, somewhat cubical cells of the bark.

[1] *Clematis virginiana* is simpler in structure than some of the other woody species. *Aristolochia* sections will do very well.

Note:

(*a*) The general outline of the section.

(*b*) The number and arrangement of the bundles. (How many kinds of bundles are there?)

(*c*) The comparative areas occupied by the woody part of the bundle and by the part which belongs to the bark.

(*d*) The way in which the pith and the outer bark are connected (and the bundles separated) by the *medullary rays*.

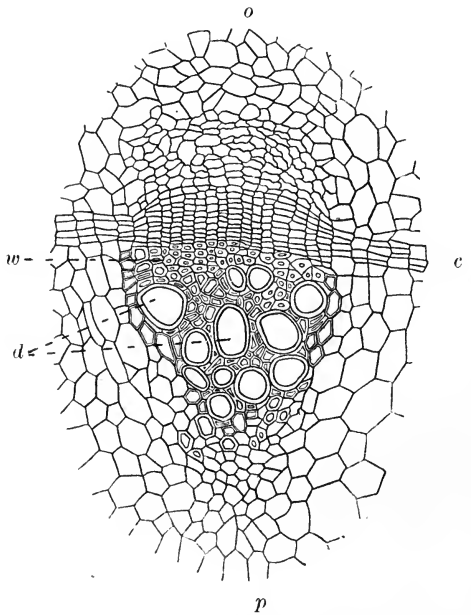


FIG. 57. — One Bundle from the Preceding Figure. (× 100.)
w, wood-cells; *d*, ducts. The other letters are as in Fig. 56. Many sieve-cells occur in the region just outside of the cambium of the bundle.

Examine a longitudinal section of the same kind of stem, to find out more accurately of what kinds of cells the pith, the bundles, and the outer bark are built. Which portion has cells that are nearly equal in shape, as seen in both sections?

102. Mechanical Importance of Distribution of Material in the Dicotyledonous Stem. — It is easy to see that those tissues which are tough, like hard bast, and those which are both tough and stiff, like wood fibers, are arranged in a tubular fashion in young dicotyledonous stems as they are in some monocotyledonous ones (Fig. 53). Sometimes the interior of the stem is quite hollow, as, for example,

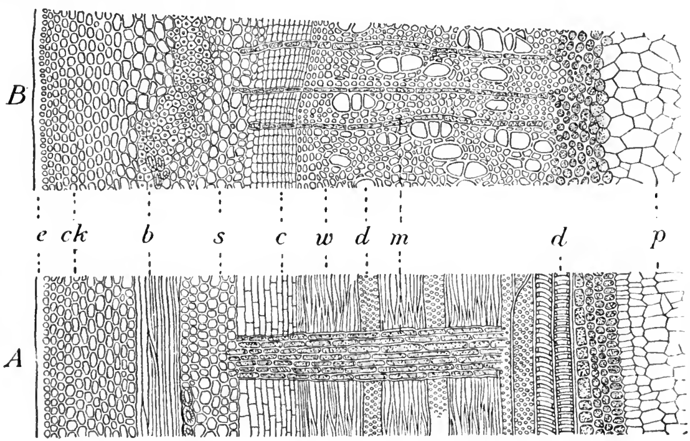


FIG. 58. — Stem of Box-Elder One Year Old. (Much magnified.)
A, lengthwise (radial) section; *B*, cross-section; *e*, epidermis; *ck*, cork; *b*, hard bast; *s*, sieve-cells; *c*, cambium; *w*, wood-cells; *m*, medullary rays; *d*, ducts; *p*, pith.

in the stems of balsams, melons, cucumbers, and squashes, and in the flower-stalks of the dandelion. In older stems, such as the trunks of trees, the wood forms a pretty nearly solid cylinder.

Stiffness in dicotyledonous stems is secured mainly in two ways: (1) by hard bast fibers, (2) by wood fibers. Which of these types does the stem (Fig. 55) represent? Which does the flax-stem (Fig. 60) represent?

Notice that in both types bast fibers and wood fibers are present, but the proportions in (1) and (2) vary greatly.

103. Kinds of Cells which compose Stems. — The student has already seen something of cells in the seed, in the roots of seedlings and mature plants, and in several kinds of stems. But he will need to become acquainted with a much larger variety of cells in the stem. The following materials will serve to illustrate some of the most important forms.[1]

Examine with a half-inch objective and one-inch eyepiece (or higher power) these preparations (1–9 below):

Study very carefully each of the sections described, find in it the kind of cell referred to in the corresponding number (1–9) of the following section (104), and make a good sketch of a group of cells of each kind as actually seen under the microscope.[2]

(1) Very thin sections of the epidermis of a potato, some cut parallel to the surface (*tangential*), others cut at right angles to the epidermis.

(2) Thin sections of the green layer of the bark of Forsythia, spindle tree (*Euonymus*), or box-elder (*Negundo*).

(3) Thin cross-sections and longitudinal sections of the inner bark of linden twigs, or of full-grown stems of flax.

(4) Longitudinal sections of the stem of squash or cucumber plants.

(5) Thin cross-sections of young twigs of pine or oak, cut in late summer.

(6) Thin cross-sections and longitudinal sections, cut from pith toward bark (*radial*) of young wood of sycamore, of sassafras, or of box-elder.

(7) Thin longitudinal sections of the stem of castor-oil plant (*Ricinus*) or of the stalk (peduncle) on which the fruit of the banana is supported.

[1] These studies may be made from sections cut by the pupil, by the teacher, or by a professional hand, as circumstances may dictate. The soft bast (No. 4, see p. 91) can best be studied in good prepared sections obtained of the dealers.

[2] Nothing can do so much to make these studies valuable as for the teacher to correct in class the errors of most frequent occurrence in the drawings, by aid of his own *camera lucida* drawings of the same objects.

(8) Thin longitudinal radial sections of sycamore, of sassafras, maple, or box-elder wood.

(9) Thin sections of elder pith, sunflower-stem pith, or of so-called Japanese "rice-paper."

104. Names of the Cells of Bark, Wood, and Pith. — No two varieties of stems will be found to consist of just the

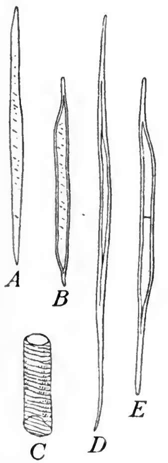


FIG. 59. — *A*, *B*, *C*, *D*, Isolated Wood-Cells and Bast-Cells of Linden.

A, *B*, wood fibers; *C*, piece of a vessel; *D*, bast fiber; *E*, a partitioned, woody fiber from European ivy. (Much magnified.)

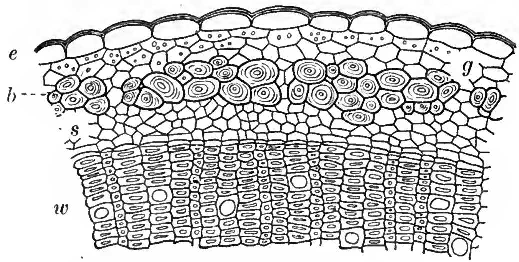


FIG. 60. — Part of Cross-Section of Stem of Flax. (Much magnified.)

e, epidermis; *b*, hard bast; *s*, sieve-cells; *w*, wood.

same kinds of cells, present in the same proportions, but it is easy to refer to illustrations which will serve to identify the kinds of cells found in the studies of the preceding section. They are:

(1) Cork-cells of the epidermis (*e.g.*, flax, Fig. 60, *e*).

(2) Cells of the green bark (*e.g.*, flax, Fig. 60), between *b* and *e*.

(3) Hard bast (Fig. 60).

(4) Soft bast (*e.g.*, flax, Fig. 60, *s*, for the cross-section and (very greatly magnified) Figs. 63, 64, for the lengthwise section).[1]

[1] The sieve-tubes shown in these figures are only one of several kinds of cell found in soft bast, but they are the most peculiar and characteristic ones. (See Strasburger, Noll, Schenk, and Schimper's *Text-Book*, pp. 102–104.)

(5) Cambium (*e.g.*, Fig. 57, *c*).
(6) Wood-cells (*e.g.*, Figs. 58, 72–73).
(7) Vessels or ducts (*e.g.*, Figs. 58 and 62).
(8) Wood parenchyma (*e.g.*, Figs. 58 and 72 in the medullary rays).
(9) Pith (*e.g.*, Figs. 55, 57).

105. Structure of Coniferous Wood. — In the wood of the cone-bearing trees of the pine family regular ducts or

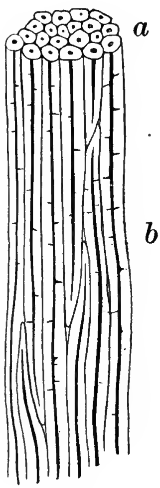


FIG. 61.

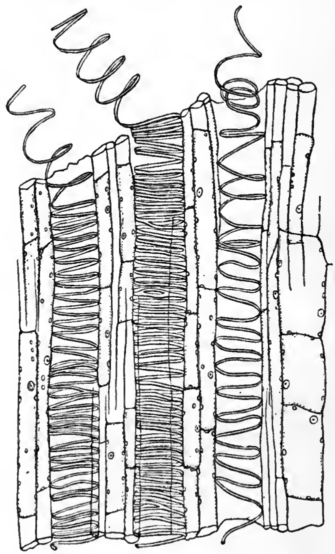


FIG. 62.

FIG. 61. — A Group of Hard Bast Fibers. (Greatly magnified.) *a*, cut-off ends ; *b*, lengthwise section of fibers.

FIG. 62. — A Lengthwise Section (greatly magnified) of a Group of Spiral Vessels from the Stem of Sunflower. At the top of the figure some of the spiral threads which line the vessels are seen partly uncoiled.

vessels are lacking. The main bulk of the wood is composed of long cells (often called *tracheids*), marked with peculiar pits. These pits, when young, are shaped much like two perforated watch-glasses, placed against a piece of cardboard, with their concave sides toward each other

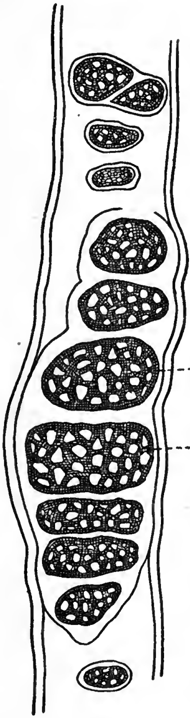


FIG. 63.

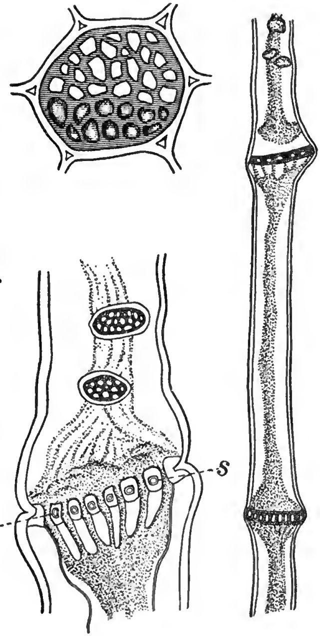


FIG. 64.

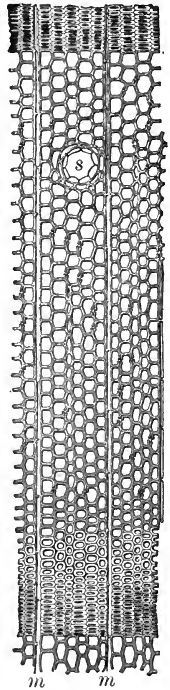


FIG. 65.

FIG. 63. — Part of a Sieve-Tube from Linden.

s, sieve-plates on the cell-wall. (× about 900.)

FIG. 64. — Parts of Sieve-Tubes as found in Plants of the Gourd Family. (Greatly magnified.)

s, *s*, a sieve-plate seen edgewise; above it a similar one, surface view.

FIG. 65. — Cross-Section of Fir Wood.

s, a resin passage; *m*, medullary rays. (Much magnified.)

(see Fig. 66, t″). The cardboard represents a part of the cell-wall common to two adjacent cells, and the watch-glasses are like the convex border bulging into each cell. When the cells grow old the partition in each pit very commonly breaks away and leaves a hole in the cell-wall.

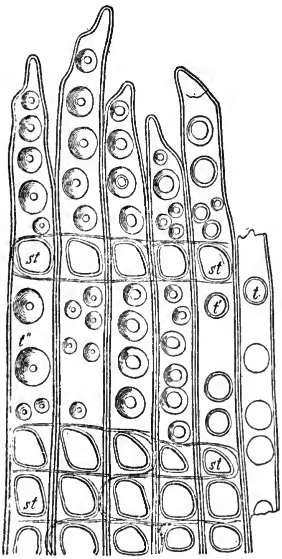


FIG. 66. — Longitudinal Radial Section through a Rapidly Growing Young Branch of Pine.

t, t′, t″, bordered pits on wood-cells; *st*, large pits where medullary rays lie against wood-cells. (Much magnified.)

106. Tissues. — A mass of similar coöperating cells is called a *tissue*.[1] Two of the principal classes which occur in the stem are *parenchymatous* tissue and *prosenchymatous* tissue. *Parenchyma* is well illustrated by the green layer of the bark, by wood parenchyma, and by pith. Its cells are usually somewhat roundish or cubical, at any rate not many times longer than wide, and at first pretty full of protoplasm. Their walls are not generally very thick.[2] *Prosenchyma*, illustrated by hard bast and masses of wood-cells, consists of thick-walled cells many times longer than wide, containing little protoplasm and often having little or no cell-cavity.

As a rule the stems of the most highly developed plants owe their toughness and their stiffness mainly to prosen-

[1] See Vines' *Students' Text-Book of Botany*, London, 1894, pp. 131–144.

[2] Excepting when they are dead and emptied, like those of old pith.

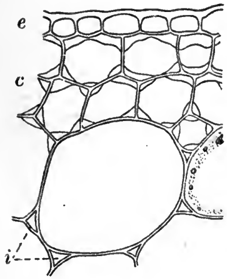


FIG. 67. — Collenchymatous and Other Tissue from Stem of Balsam (*Impatiens*).

e, epidermis; *c*, collenchyma; *i*, intercellular spaces between large parenchyma-cells.

chymatous tissue. In some (particularly in fleshy) stems the stiffness is, however, largely due to *collenchyma*, a kind of parenchyma in which the cells are thickened or reinforced at their angles, as shown in Fig. 67.

107. Early History of Stem-Structure. — In the very young parts of stems, such, for instance, as the growing point between the two rudimentary leaves of a bean-plumule, the cells are all of thin-walled *formative tissue* and look a good deal alike. This condition of things is quickly succeeded by one in which there is a cylinder (appearing in cross-sections of the stem as a ring) of actively growing tissue *x* (Fig. 68, *A*), lying between the cortex *r* and the pith *m*. Soon the cylinder *x* develops into a series of separate fibro-vascular bundles arranged as shown in Fig. 68, *B*, and these again in a short time unite, as shown at *C*. A comparison of this last portion of the figure with that of the

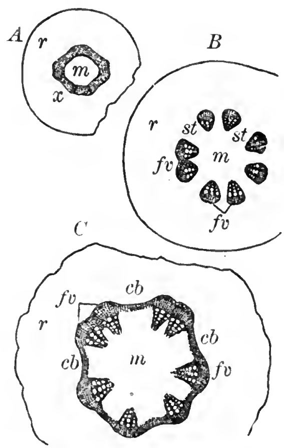


FIG. 68. — Transverse Section through the Hypocotyl of the Castor-Oil Plant at Various Stages.

A, after the root has just appeared outside the testa of the seed; *B*, after the hypocotyl is nearly an inch long; *C*, at the end of germination; *r*, cortex (undeveloped bark); *m*, pith; *st*, medullary rays; *fv*, fibro-vascular bundles; *cb*, layer of tissue which is to develop into cambium. (Considerably magnified.)

one-year-old Aristolochia-stem (Fig. 56) shows a decided similarity between the two. In both cases we have the central pith, the regularly grouped bundles, and cambium (or in Fig. 68, *C*, a tissue which will grow into cambium), — part of it in the bundles and part of it between them.

In the young monocotyledonous stem the grouping of the bundles is less regular than that just explained. This is shown by Fig. 52. A much more important difference consists in the fact that the monocotyledonous stem has usually no permanent living cambium ring. Annual dicotyledons, however, are also destitute of permanent cambium.

108. Secondary Growth. — From the inside of the cambium layer the wood-cells and ducts of the mature stem are produced, while from its outer circumference proceed the new layers of the inner bark, composed largely of sieve-cells and hard bast. From this mode of increase the stems of dicotyledonous plants are called *exogenous*, that is, outside-growing. The presence of the cambium layer on the outside of the wood in early spring is a fact well known to the schoolboy, who pounds the cylinder cut from an elder, willow, or hickory branch until the bark will slip off and so enable him to make a whistle. The sweet taste of this pulpy layer, as found in the white pine, the slippery elm, and the basswood, is a familiar evidence of the nourishment which the cambium layer contains.

With the increase of the fibro-vascular bundles of the wood the space between them, which appears relatively large in Fig. 68, becomes less and less, and the pith, which at first extended freely out toward the circumference of the stem, is at length only represented by thin plates, the medullary rays.

These are of use in storing the food which the plant in cold and temperate climates lays up in the summer and fall for use in the following spring, and in the very young stem they serve as an important channel for the transference of fluids across the stem from bark to pith, or in the

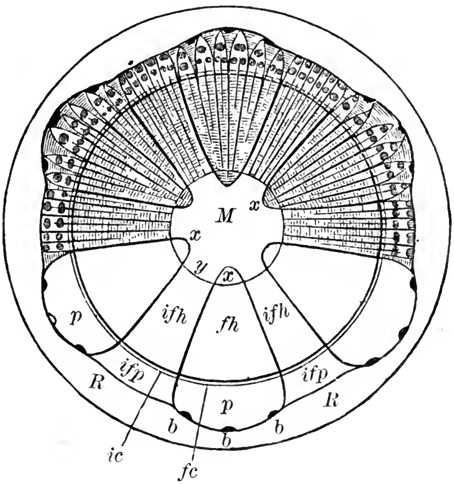


FIG. 69. — Diagram to illustrate Secondary Growth in a Dicotyledonous Stem.

R, the first-formed bark; *p*, mass of sieve-cells; *ifp*, mass of sieve-cells between the original wedges of wood; *fc*, cambium of wedges of wood; *ic*, cambium between wedges; *b*, groups of bast-cells; *fh*, wood of the original wedges; *ifh*, wood formed between wedges; *x*, earliest wood formed; *M*, pith.

reverse direction. On account, perhaps, of their importance to the plants, the cells of the medullary rays are among the longest lived of all plant-cells, retaining their vitality in the beech tree sometimes, it is said, for more than a hundred years.

After the interspaces between the first fibro-vascular bundles have become filled up with wood, the subsequent growth must take place in the manner shown in Fig. 69. All the cambium, both that of the original wedges of wood, *fc*, and that, *ic*, formed later between these wedges, continues to grow from its inner and from its outer face, and thus causes a permanent increase in the diameter of the stem and a thickening of the bark, which, however, usually at an early period begins to peel off from the outside and thus soon attains a pretty constant thickness.[1] It will be noticed, in the study of dicotyledonous stems more than a year old, that there are no longer any separate fibro-vascular bundles. The process just described has covered the original ring of bundles with layer after layer of later formed wood-cells, and the wood at length is arranged in a hollow cylinder.

It is the lack of any such ring of cambium as is found in dicotyledonous plants, or even of permanent cambium in the separate bundles, that makes it impossible for the trunks of most palm trees (Fig. 54) to grow indefinitely in thickness, like that of an oak or an elm.[2]

109. Grafting. — When the cambium layer of any vigorously growing stem is brought in contact with this layer in another stem of the same kind or a closely similar kind of plant, the two may grow together to form a single stem or branch. This process is called *grafting*, and is much resorted to in order to secure apples, pears, etc., of any desired kind. A twig from a tree of the chosen variety is grafted on to any kind of tree *of the same species* (or sometimes a related species), and the resulting stems will bear the wished-for kind of fruit. Sometimes grafting comes

[1] See Vines' *Students' Text-Book of Botany*, London, 1894, pp. 211, 212.

[2] See, however, Strasburger, Noll, Schenk and Schimper's *Text-Book*, pp. 138, 139.

about naturally by the branches of a tree chafing against one another until the bark is worn away and the cambium layer of each is in contact with that of the other, or two separate trees may be joined by natural grafting, as is shown in Fig. 70.

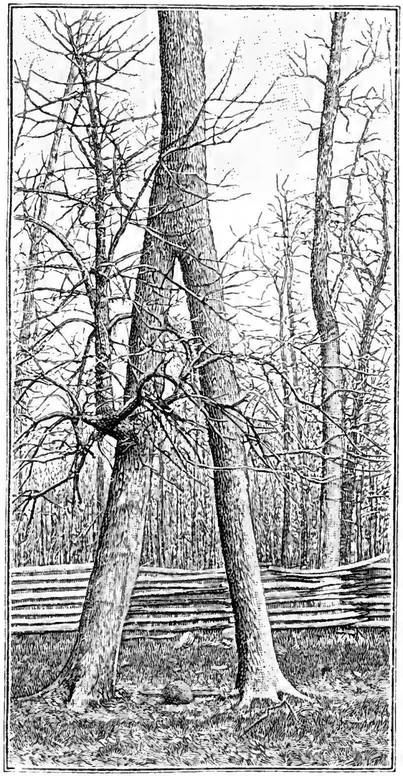


FIG. 70. — Two Ash Trees naturally grafted together.

110. Stem-Structure of Climbing Shrubs. — Some of the most remarkable kinds of dicotyledonous stems are found in climbing shrubs. The structure of many of these is too complicated to be discussed in a botany for beginners, but one point in regard to them is of much interest. The bundles (as seen in the clematis and shown in Fig. 56) are much more distinct than in most other woody stems. Even after several years of growth the wood is often found to be arranged in a number of flattish twisted strands. It is evident that this is for the sake of leaving the stem flexible for twining purposes, just as a wire cable is adapted to be wound about posts or other supports, while a solid steel or iron rod of the same size would be too stiff for this use.

111. The Dicotyledonous Stem, thickened by Secondary Growth. — Cut off, as smoothly as possible, a small branch of hickory and one of white oak above and below each of the rings of scars already mentioned (Sect. 77), and count the rings of wood above and below each ring of scars.

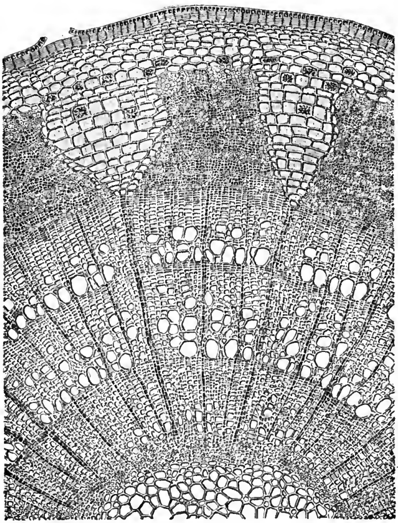


FIG. 71. — Cross-Section of a Three-Year-Old Linden Twig. (Much magnified.)

P, epidermis and corky layer of the bark; *Phl*, bast; *C*, cambium layer; *JR*, annual rings of wood.

How do the numbers correspond? What does this indicate?

Count the rings of wood on the cut-off ends of large billets of some of the following woods: locust, chestnut, sycamore, oak, hickory.

Do the successive rings of the same tree agree in thickness?

Why? or why not?

Does the thickness of the rings appear uniform all the way round the stick of wood? If not, the reason in the case of an upright stem (trunk) is perhaps that there was a greater spread of leaves on the side where the rings are thickest[1] or because there was unequal pressure, caused by bending before the wind.

Do the rings of any one kind of tree agree in thickness with those of all the other kinds? What does this show?

In all the woods examined look for:

(*a*) Contrasts in color between the heartwood and the sapwood.[2]

[1] See Sect. 118.

[2] This is admirably shown in red cedar, black walnut, barberry, black locust and osage orange.

(*b*) The narrow lines running in very young stems pretty straight from pith to bark, in older wood extending only a little of the way from center to bark, the *medullary rays*, shown in Fig. 72.[1]

(*c*) The wedge-shaped masses of wood between these.

(*d*) The pores which are so grouped as to mark the divisions between successive rings. These pores indicate the cross-sections of *vessels* or *ducts*. Note the distribution of the vessels in the rings to which they belong, compare this with Figs. 58, 72, and decide at what season of the year the largest ducts are mainly produced. Make a careful drawing of the end-section of one billet of wood, natural size.

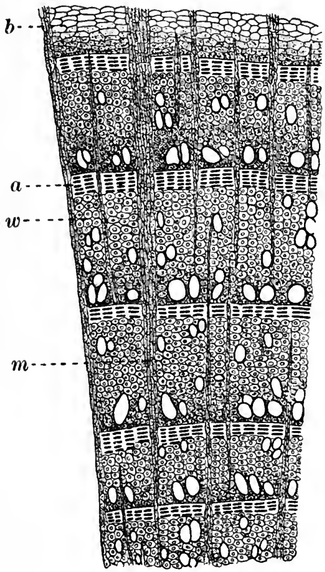


FIG. 72. — Cross-Section of Beech-Wood. *b*, bark; *a*, flattened cells formed near end of each year's growth; *w*, regular wood-cells; *m*, medullary ray.

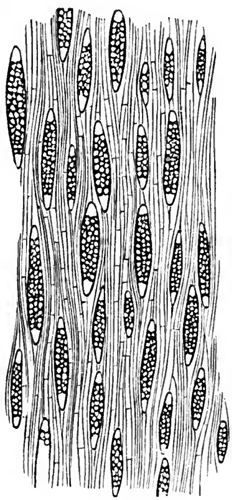


FIG. 73. — Longitudinal Section of Mahogany at Right Angles to Medullary Rays, showing Cut-off Ends. (Much magnified.)

Cut off a grapevine several years old and notice the great size of

[1] These and many other important things are admirably shown in the thin wood-sections furnished for $4 per set of 24 by R. B. Hough, Lowville, N. Y.

the vessels. Examine the smoothly planed surface of a billet of red oak that has been split through the middle of the tree (quartered oak), and note the large shining plates formed by the medullary rays.

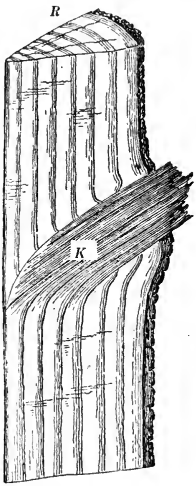


FIG. 74. — Formation of a Knot in a Tree-Trunk.

R, cut-off end of stick, showing annual rings; *K*, knot, formed by growth of a branch.

Look at another stick that has been planed away from the outside until a good-sized flat surface is shown, and see how the medullary rays are here represented only by their edges.

112. Interruption of Annual Rings by Branches; Knots. — When a leaf-bud is formed on the trunk or branch of a dicotyledonous tree, it is connected with the wood by fibro-vascular bundles. As the bud develops into a branch, the few bundles which it originally possessed increase greatly in number, and at length, as the branch grows, form a cylinder of wood which cuts across the annual rings, as shown in Fig. 74. This interruption to the rings is a knot, such as one often sees in boards and planks. If the branch dies long before the tree does, the knot may be buried under many rings of wood. What is known as clear lumber is obtained from trees that have grown in a dense forest, so that the lower branches of the larger trees were killed by the shade many years before the tree was felled.

In pruning fruit trees or shade trees the branches which are removed should be cut close to the trunk. If this is done, the growth of the trunk will bury the scar before decay sets in.

113. Comparison of the Monocotyledonous and the Dicotyledonous Stem.[1]

	Monocotyledonous Stem	Dicotyledonous Stem
General Structure.	A hard rind of rather uniform structure. Bundles intermixed with the pith.	A complex bark, usually on young shoots consisting of a corky layer, a green layer, and a layer of bast. Wood in annual rings. Pith in a cylinder at the center.
Structure of Bundles.	Bundles *closed*, that is, without permanent cambium.	Bundles *open*, with permanent cambium.
Growth in Thickness.	Cells of mature parts of stem expand somewhat, but (in most palms) new ones are not found.	New wood-cells formed throughout growing season from cambium ring.

114. Review Sketches and Diagrams.

(1) Monocotyledonous stem (lengthwise section).
(2) Dicotyledonous stem (lengthwise section).
(3) First appearance of bundles in dicotyledonous stem.
(4) Dicotyledonous stem five years or more old (cross-section).
(5) Various bark-cells.
(6) Various cells from wood.
(7) Pith-cells.
(8) Collenchyma-cells.

[1] This comparison applies only to most of the woody or tree-like stems.

CHAPTER VII

LIVING PARTS OF THE STEM; WORK OF THE STEM

115. Active Portions of the Stems of Trees and Shrubs. — In annual plants generally and in the very young shoots of shrubs and trees there are *stomata* or breathing pores which occur abundantly in the epidermis, serving for the admission of air and the escape of moisture, while the green layer of the bark answers the same purpose that is served by the green pulp of the leaf (Chapter XI). For years, too, the spongy lenticels, which succeed the stomata and occur scattered over the external surface of the bark of trees and shrubs, serve to admit air to the interior of the stem. The lenticels at first appear as roundish spots, of very small size, but as the twig or shoot on which they occur increases in diameter the lenticel becomes spread out at right angles to the length of the stem, so that it sometimes becomes a longer transverse slit or scar on the bark, as in the cherry and the birch. But in the trunk of a large tree no part of the bark except the inner layer is alive. The older portions of the bark, such as the highly developed cork of the cork-oak, from which the ordinary stoppers for bottles are made, sometimes cling for years after they are dead and useless except as a protection for the parts beneath against mechanical injuries or against cold. But in many cases, as in the shell-bark hickory and the grapevine, the old bark soon falls off in strips; in birches it finally peels off in bands around the stem.

The cambium layer is very much alive, and so is the young outer portion of the wood. Testing this "sap-wood," particularly in winter, shows that it is rich in starch and proteids.

The heartwood of a full-grown tree is hardly living, unless the cells of the medullary rays retain their vitality, and so it may be that wood of this kind is useful to the tree mainly by giving stiffness to the trunk and larger branches, thus preventing them from being easily broken by storms.

It is, therefore, possible for a tree to flourish, sometimes for centuries, after the heartwood has much of it rotted away and left the interior of the trunk hollow, as shown in Fig. 75.

116. Uses of the Components of the Stem. — There is a marked division of labor among the various groups of cells that make up the stem of ordinary dicotyledons, particularly in the stems of trees, and it will be best to explain the uses of the kinds of cells as found in trees, rather than in herbaceous plants. A few of the ascertained uses of the various tissues are these:

The pith forms a large part of the bulk of very young shoots, since it is a part of the tissue of comparatively simple structure amid which the fibro-vascular bundles arise. In mature stems it becomes rather unimportant, though it often continues for a long time to act as a storehouse of food.

The medullary rays in the young shoot serve as a channel for the transference of water and plant-food in a liquid form across the stem, and they often contain much stored food.

FIG. 75.—Pioneer's Cabin, a Very Large Hollow Sequoia.

The vessels carry water upward and (sometimes) air downward through the stem.

The wood-cells of the heartwood are useful only to give stiffness to the stem. Those of the sapwood, in addition to this work, have to carry most of the water from the roots to the leaves and other distant portions of the plant.

The cambium layer is the region in which the annual growth of the tree takes place (Figs. 69, 71).

The most important portion of the inner bark is that which consists of sieve-tubes, for in these digested and elaborated plant-food is carried from the leaves toward the roots.

The green layer of the bark in young shoots does much toward collecting nutrient substances, or raw materials, and preparing the food of the plant from air and water, but this work may be best explained in connection with the study of the leaf (Chapter XI).

117. Movement of Water in the Stem. — The student has already learned that large quantities of water are taken up by the roots of plants.

Having become somewhat acquainted with the structure of the stem, he is now in a position to investigate the question how the various fluids, commonly known as sap, travel about in it.[1] It is important to notice that sap is by no means the same substance everywhere and at all times. As it first makes its way by osmotic action inward through the root-hairs of the growing plant it differs but little from ordinary spring water or well water. The liquid which flows from the cut stem of a "bleeding" grapevine which has been pruned just before the buds have begun to burst in the spring, is mainly water with a little dissolved mucilaginous material. The sap which is

[1] See the paper on "The So-called Sap of Trees and its Movements," by Professor Charles R. Barnes, *Science*, Vol. XXI, p. 535.

obtained from maple trees in late winter or early spring, and is boiled down for syrup or sugar, is still richer in nutritious material than the water of the grapevine, while the elaborated sap which is sent so abundantly into the ear of corn, at its period of filling out, or into the growing pods of beans and peas, or into the rapidly forming acorn or the chestnut, contains great stores of food, suited to sustain plant or animal life.

EXPERIMENT XXI

Rise of Water in Stems. — Cut some short branches from an apple tree or a cherry tree and stand the lower end of each in red ink; try the same experiment with twigs of oak, ash, or other porous wood, and after some hours[1] examine with the magnifying glass and with the microscope, using the 2-inch objective, successive cross-sections of one or more twigs of each kind. Note exactly the portions through which the ink has traveled. Pull off the leaves from one of the stems after standing in the eosin solution, and notice the spots on the leaf-scar through which the eosin has traveled. These spots show the positions of the *leaf-traces*, or fibro-vascular bundles, connecting the stem and the leaf. Repeat with several potatoes, cut crosswise through the middle. Try also some monocotyledonous stems, such as those of the lily or asparagus. For the sake of comparison between roots and stems, treat any convenient root, such as a parsnip, in the same way.

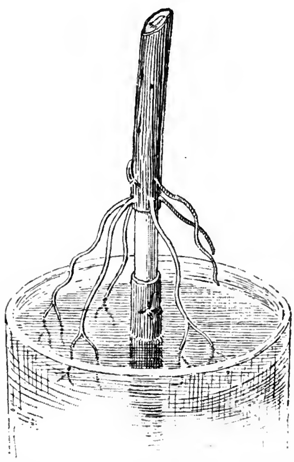


FIG. 76. — A Cutting girdled and sending down Roots from the Upper Edge of the Girdled Ring.

[1] If the twigs are leafy and the room is warm, only from 5 to 30 minutes may be necessary.

Examine longitudinal sections of some of the twigs, the potatoes, and the roots. In drawing conclusions about the channels through which the ink has risen (those through which the newly absorbed soil-water most readily travels), bear in mind the fact that a slow soakage of the red ink will take place in all directions, and therefore pay attention only to the strongly colored spots or lines.

What conclusions can be drawn from this experiment as to the course followed by the sap?

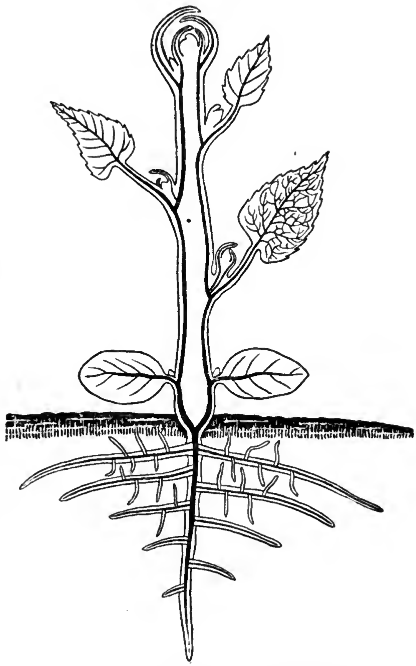


FIG. 77. — Channels for the Movement of Water, upward and downward.

The heavy black lines in roots, stems, and leaves show the course of the fibro-vascular bundles through which the principal movements of water take place.

From the familiar facts that ordinary forest trees apparently flourish as well after the almost complete decay and removal of their heartwood, and that many kinds will live and grow for a considerable time after a ring of bark extending all round the trunk has been removed, it may readily be inferred that the crude sap in trees must rise through some portion of the newer layers of the wood. A tree girdled by the removal of a ring of sapwood promptly dies.

118. Downward Movement of Liquids. — Most dicotyledonous stems, when stripped of a ring of bark and then stood in water, as shown in Fig. 76, and covered with a bell-jar, develop roots only at or near the upper edge of the stripped portion,[1] and this would seem to prove that such stems send their building material — the elaborated sap — largely at any rate down through the bark. Its course is undoubtedly for the most part through the sieve-cells (Figs. 63, 64), which are admirably adapted to convey liquids. In addition to these general upward and downward movements of sap, there must be local transfers laterally through the stem, and these are at times of much importance to the plant.

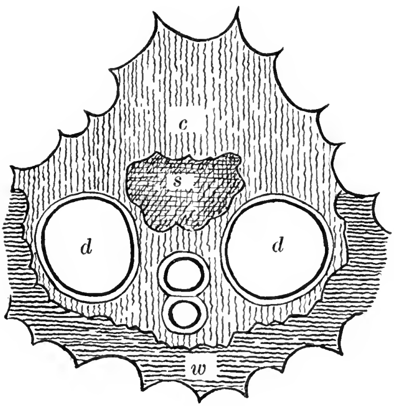


Fig. 78. — Diagrammatic Cross-Section of a Bundle from Sugar-Cane, showing Channels for Air and Water. (Magnified.)

Air travels downward through the two large ducts *d* (and the two smaller ones between them). Water travels upward through the ducts and through the wood-cells in the region marked *w*. Water with dissolved plant-food travels downward through the sieve-cells in the region marked *s*.

Since the liquid building material travels straight down the stem, that side of the stem on which the manufacture of such material is going on most rapidly should grow fastest.

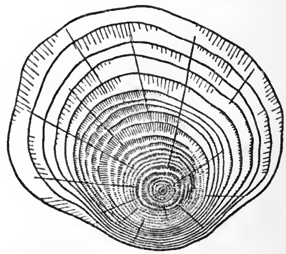


Fig. 79. — Unequal Growth of Rings of Wood in nearly Horizontal Stem of a Juniper. (Natural size.)

[1] This may be made the subject of a protracted class-room experiment. Strong shoots of willow should be used for the purpose.

Plant-food is made out of the raw materials by the leaves, and so the more leafy side of a tree forms thicker rings than the less leafy side, as shown in Fig. 79.

119. Rate of Movement of Water in the Stem. — There are many practical difficulties in the way of ascertaining exactly how fast the watery sap travels from the root to the leaves. It is, however, easy to illustrate experimentally the fact that it does rise, and to give an approximate idea of the time required for its ascent. The best experiment for beginners is one which deals with an entire plant under natural conditions.

EXPERIMENT XXII

Wilting and Recovery. — Allow a fuchsia or a hydrangea [1] which is growing in a flower-pot to wilt considerably for lack of watering. Then water it freely and record the time required for the leaves to begin to recover their natural appearance and position, and the time fully to recover.

The former interval of time will give a very rough idea of the time of transfer of water through the roots and the stem of the plant. From this, by measuring the approximate distance traveled, a calculation could be made of the number of inches per minute that water travels in this particular kind of plant, through a route which is partly roots, partly stem, and partly petiole. Still another method is to treat leafy stems as the student in Exp. XXI treated the twigs which he was examining, and note carefully the rate of ascent of the coloring liquid. This plan is likely to give results that are too low, still it is of some use. It has given results varying from 34 inches per

[1] *Hydrangea Hortensia.*

hour for the willow to 880 inches per hour for the sunflower. A better method is to introduce the roots of the plant which is being experimented upon into a weak solution of some chemical substance which is harmless to the plant and which can readily be detected anywhere in the tissues of the plant by chemical tests. Proper tests are then applied to portions of the stem which are cut from the plant at short intervals of time.

Compounds of the metal lithium are well adapted for use in this mode of experimentation.

120. Causes of Movements of Water in the Stem. — Some of the phenomena of osmosis were explained in Sect. 62, and the work of the root-hairs was described as due to osmotic action.

Root-pressure (Sect. 66), being apparently able to sustain a column of water only 80 or 90 feet high at the most, and usually less than half this amount, would be quite insufficient to raise the sap to the tops of the tallest trees, since many kinds grow to a height of more than 100 feet. Our Californian "big trees," or Sequoias, reach the height of over 300 feet, and an Australian species of Eucalyptus, it is said, sometimes towers up to 470 feet. Root-pressure, then, may serve to start the soil-water on its upward journey, but some other force or forces must step in to carry it the rest of the way. What these other forces are is still a matter of discussion among botanists.

The slower inward and downward movement of the sap may be explained as due to osmosis. For instance, in the case of growing wood-cells, sugary sap descending from the leaves into the stem gives up part of its sugar to form the cellulose of which the wood-cells are being made.

This loss of sugar would leave the sap rather more watery than usual, and osmosis would carry it from the growing wood to the leaves, while at the same time a slow transfer of the dissolved sugar will be set up from leaves to wood. The water, as fast as it reaches the leaves, will be thrown off in the form of vapor, so that they will not become distended with water, while the sugar will be changed into cellulose and built into new wood-cells as fast as it reaches the region where such cells are being formed.

Plants in general[1] readily change starch to sugar, and sugar to starch. When they are depositing starch in any part of the root or stem for future use, the withdrawal of sugar from those portions of the sap which contain it most abundantly gives rise to a slow movement of dissolved particles of sugar in the direction of the region where starch is being laid up.

121. Storage of Food in the Stem.—The reason why the plant may profit by laying up a food supply somewhere inside its tissues has already been suggested (Sect. 91).

The most remarkable instance of storage of food in the stem is probably that of sago-palms, which contain an enormous amount, sometimes as much as 800 pounds, of starchy material in a single trunk. But the commoner plants of temperate regions furnish plenty of examples of deposits of food in the stem. As in the case of seeds and roots, starch constitutes one of the most important kinds of this reserve material of the stem, and since it is easier to detect than any other food material which the plant stores, the student will do well to spend time in looking for starch only.

[1] Not including most of the flowerless and very low and simple kinds.

Cut thin cross-sections of twigs of some common deciduous tree or shrub, in its early winter condition, moisten with iodine solution, and examine for starch with a moderately high power of the microscope. Sketch the section with a pencil, coloring the starchy portions with blue ink, used with a mapping pen, and describe exactly in what portions the starch is deposited.

122. Storage in Underground Stems. — The branches and trunk of a tree furnish the most convenient place in which to deposit food during winter to begin the growth of the following spring. But in those plants which die down to the ground at the beginning of winter the storage must be either in the roots, as has been described in Sect. 58, or in underground portions of the stem.

Rootstocks, tubers, and bulbs seem to have been developed by plants to answer as storehouses through the winter (or in some countries through the dry season) for the reserve materials which the plant has accumulated during the growing season. The commonest tuber is the potato, and this fact and the points of interest which it represents make it especially desirable to use for a study of the underground stem in a form most highly specialized for the storage of starch and other valuable products.

123. A Typical Tuber: the Potato. — Sketch the general outline of a potato, showing the attachment to the stem from which it grew.[1]

Note the distribution of the "eyes," — are they opposite or alternate? Examine them closely with the magnifying glass and then with the lowest power of the microscope. What do they appear to be?

If the potato is a stem, it may branch, — look over a lot of potatoes to try to find a branching specimen. If such a one is secured, sketch it.

[1] Examination of a lot of potatoes will usually discover specimens with an inch or more of attached stem.

Note the little scale overhanging the edge of the eye, and see if you can ascertain what this scale represents.

Cut the potato across, and notice the faint broken line which forms a sort of oval figure some distance inside the skin.

Place the cut surface in eosin solution, allow the potato to stand so for many hours, and then examine, by slicing off pieces parallel to the cut surface, to see how far and into what portions the solution has penetrated. Refer to the notes on the study of the parsnip (Sect. 56), and see how far the behavior of the potato treated with eosin solution agrees with that of the parsnip so treated.

Cut a thin section at right angles to the skin, and examine with a high power. Moisten the section with iodine solution and examine again.

If possible, secure a potato which has been sprouting in a warm place for a month or more (the longer the better), and look near the origins of the sprouts for evidences of the loss of material from the tuber.

EXPERIMENT XXIII

Use of the Corky Layer. — Carefully weigh a potato, then pare another larger one, and cut portions from it until its weight is made approximately equal to that of the first one. Expose both freely to the air for some days and reweigh. What does the result show in regard to the use of the corky layer of the skin?

124. Morphology of the Potato. — It is evident that in the potato we have to do with a very greatly modified form of stem. The corky layer of the bark is well represented, and the loose cellular layer beneath is very greatly developed; wood is almost lacking, being present only in the very narrow ring which was stained by the red ink, but the pith is greatly developed and constitutes the principal bulk of the tuber. All this is readily understood if we consider that the tuber, buried in and supported by the earth, does not need the kinds of tissue which give strength, but only those which are well adapted to store the requisite amount of food.

125. Structure of a Bulb; the Onion. — Examine the external appearance of the onion and observe the thin membranaceous skin which covers it. This skin consists of the broad sheathing bases of the outer leaves which grew on the onion plant during the summer. Remove these and notice the thick scales (also formed from bases of leaves as shown in Fig. 48) which make up the substance of the bulb.

Make a transverse section of the onion at about the middle and sketch the rings of which it is composed. Cut a thin section from the interior of the bulb, examine with a moderate power of the microscope, and note the thin-walled cells of which it is composed.

Split another onion from top to bottom and try to find:

(*a*) The *plate* or broad flattened stem inside at the base (Fig. 47).

(*b*) The central bud.

(*c*) The bulb-scales.

(*d*) In some onions (particularly large, irregular ones) the bulblets or side buds arising in the axes of the scales near the base.

Test the cut surface for starch.

126. Sugar in the Onion. — *Grape sugar* is an important substance among those stored for food by the plant. It received its name from the fact that it was formerly obtained for chemical examination from grapes. Old dry raisins usually show little masses of whitish material scattered over the skin which are nearly pure grape sugar. Commercially it is now manufactured on an enormous scale from starch by boiling with diluted sulphuric acid. In the plant it is made from starch by processes as yet imperfectly understood, and another sugar, called *maltose*, is made from starch in the seed during germination.

Both grape sugar and maltose (and hardly any other substances) have the power of producing a yellow or orange color and throwing down an orange or reddish deposit, when they are added to a brilliant blue alkaline solution of copper, known as *Fehling's solution.*[1] The color or deposit will not appear until the solution has been heated to boiling.

EXPERIMENT XXIV

Testing for Grape Sugar. — Heat to boiling in a test-tube or a small beaker some weak syrup of grape sugar or some honey, much diluted with water. Add Fehling's solution, a few drops at a time, until a decided orange color appears. Repeat the test with the water in which some slices of onion have been boiled, filtering the water through a paper filter and heating again to boiling before adding the test solution.[2]

127. Proteids in the Onion. — Since the onion grows so rapidly on being planted in the spring, there must be a large supply of food in the bulb; there may be other substances present besides sugar.

EXPERIMENT XXV

Testing an Onion for Other Stored Food. — Test a rather thick slice of onion by heating it in a porcelain evaporating dish with a little strong nitric acid until the latter begins to boil and the onion becomes somewhat softened.[3] Rinse off the slice of onion in a stream of water, then pour on it a few drops of ammonium hydrate and observe any change of color. What is proved? See Sect. 29.

128. Tabular Review of Experiments.

[Continue the table from Sect. 74.]

[1] For the preparation of the solution see Handbook.

[2] The deposit will in this case, even if orange at first, finally become black, probably owing to the presence of sulphur in the onion.

[3] Do not allow the acid to touch the clothing, the hands, or any metallic object.

129. Review Summary of Work of Stem.

Channels for upward movement of water
- in young dicotyledonous stems . . .
- in dicotyledonous stems several years old . . . .
- in monocotyledonous stems . .

Channels for downward movement of water
- in dicotyledonous stems . . .
- in monocotyledonous stems . .

Channels for transverse movements . . . .

Rate of upward movement . . . .

Storage of plant-food
- where stored . . . .
- kinds stored . . . .
- uses . . . .

CHAPTER VIII

BUDS

130. Structure of Buds. — While studying twigs in their winter condition, as directed in Sects. 77, 78, the student had occasion to notice the presence, position, and arrangement of buds on the branch, but he was not called upon to look into the details of their structure. The most natural time to do this is just before the study of the leaf is begun, since leafy stems spring from buds, and the rudiments of leaves in some form must be found in buds.

131. The Horse-Chestnut Bud. — Examine one of the lateral buds on a twig in its winter or early spring condition.[1]

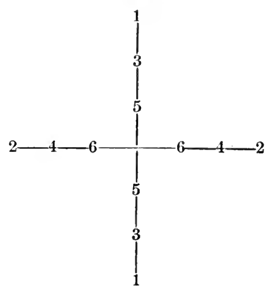
Make a sketch of the external appearance of the buds as seen with a magnifying glass.

How do the scales with which it is covered lie with reference to those beneath them?

Notice the sticky coating on the scales.

Are the scales opposite or alternate?

Remove the scales in pairs, placing them in order on a sheet of paper, thus:



Make the distance from 1 to 1 as much as 6 or 8 inches.

How many pairs are found?

Observe as the scales are removed whether the sticky coating is

[1] The best possible time for this examination is just as the buds are beginning to swell slightly in the spring. The bud of buckeye or of cottonwood will do for this examination, though each is on a good deal smaller scale than the horse-chestnut bud. Buds may be forced to open early by placing twigs in water in a very warm, light place for many weeks.

thicker on the outside or the inside of each scale, and whether it is equally abundant on all the successive pairs.

What is the probable use of this coating?

Note the delicate veining of some of the scales as seen through the magnifying glass. What does this mean?

FIG. 80. — Dissected Bud of Buckeye (*Æsculus macrostachya*), showing Transitions from Bud-Scales to Leaves.

Inside the innermost pair are found two forked woolly objects; what are these?

Compare with Figs. 87 and 107.

Their shape could be more readily observed if the woolly coating were removed.

Can you suggest a use for the woolly coating?

Examine a terminal bud in the same way in which you have just studied the lateral bud.

Does it contain any parts not found in the other?

What is the appearance of these parts?

What do they represent?

If there is any doubt about their nature, study them further on a horse-chestnut tree during and immediately after the process of leafing out in the spring.

For comparison study at least one of the following kinds of buds in their winter or early spring condition: hickory, butternut, beech, ash, magnolia (or tulip tree), lilac, balm of Gilead, cottonwood, cultivated cherry.[1]

[1] Consult the account of the mode of studying buds in Professor W. F. Ganong's *Teaching Botanist*, pp. 208–210. If some of the buds are studied at home, pupils will have a better chance to examine at leisure the unfolding process.

132. Nature of Bud-Scales. — The fact that the bud-scales are in certain cases merely imperfectly developed leaves or leaf-stalks is often clearly manifest from the series of steps connecting the bud-scale on the one hand with the young leaf on the other, which may be found in many opening buds, as illustrated by Fig. 80. In other buds the scales are not imperfect leaves, but the little appendages (*stipules*, Figs. 98, 99) which occur at the bases of leaves. This kind of bud-scale is especially well shown in the magnolia and the tulip tree.

133. Naked Buds. — All of the buds above mentioned are *winter buds*, capable of living through the colder months of the year, and are scaly buds.

In the herbs of temperate climates, and even in shrubs and trees of tropical regions, the buds are often *naked*, that is, nearly or quite destitute of scaly coverings (Fig. 81).

Make a study of the naked buds of any convenient herb, such as one of the common "geraniums" (*Pelargonium*), and record what you find in it.

Fig. 81. — Tip of Branch of *Ailanthus* in Winter Condition, showing very Large Leaf-Scars and nearly Naked Buds.

134. Position of Buds. — The distinction between *lateral* and *terminal* buds has already been alluded to.

The plumule is the first terminal bud which the plant produces. Lateral buds are usually *axillary*, as shown in Fig. 82, that is, they grow in the angle formed by the leaf with the stem (Latin *axilla*, armpit). But not infrequently there are several buds grouped in some way about

FIG. 82. — Alternate Leaves of Cultivated Cherry, with Buds in their Axils, in October.

a single leaf-axil, either one above the other, as in the butternut (Fig. 84), or grouped side by side, as in the red maple, the cherry, and the box-elder (Fig. 83).

In these cases all the buds except the axillary one are called *accessory* or *supernumerary* buds.

135. Leaf-Buds and Flower-Buds; the Bud an Undeveloped Branch. — Such buds as the student has so far examined for himself are not large enough to show in the most obvious way the relation of the parts and their real nature.

Fortunately, it is easy to obtain a gigantic terminal bud which illustrates perfectly the structure and arrangement of the parts of buds in general.

Examine and sketch a rather small, firm cabbage, preferably a red one, which has been split lengthwise through the center[1] and note

(*a*) The short, thick, conical stem.

(*b*) The crowded leaves which arise from the stem, the lower and outer ones largest and most mature, the upper and innermost ones the smallest of the series.

(*c*) The axillary buds, found in the angles made by some leaves with the stem.

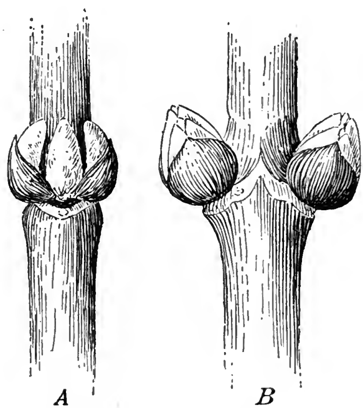


FIG. 83. — Accessory Buds of Box-Elder (*Negundo*). (Magnified.)

A, front view of group.
B, two groups seen in profile.

Compare the section of the cabbage with Fig. 86.

Most of the buds so far considered were *leaf-buds*, that is, the parts inside of the scales would develop into leaves, and their central axes into stems; but some were *mixed buds*, that is, they contained both leaves and flowers in an undeveloped condition.

Flower-buds contain the rudiments of flowers only.

Sometimes, as in the black walnut and the butternut, the leaf-buds and flower-buds are readily distinguishable

[1] Half of a cabbage will be enough for the entire division.

by their difference in form, while in other cases, as in the cultivated cherry, the difference in form is but slight.

The rings of scars about the twig, shown in Figs. 82 and 85, mark the place where the bases of bud-scales were attached. A little examination of the part of the twig which lies outside of this ring, as shown in Fig. 82, will lead one to the conclusion that this portion has all grown in the one spring and summer since the bud-scales of that particular ring dropped off. Following out this suggestion, it is easy to reckon the age of any moderately old portion of a branch, since it is equal to the number of segments between the rings. In rapidly growing shoots of willow, poplar, and similar trees, 5 or 10 feet of the length may be the growth of a single year, while in the lateral twigs of the hickory, apple, or cherry the yearly increase may be but a fraction of an inch. Such fruiting "spurs" as are shown in Fig. 85 are of little use in the permanent growth of the tree, and poplars, elms, soft maples and other trees shed the oldest of these every year. Whatever the amount of this growth, it is but the lengthening out and development of the bud, which may be regarded as an undeveloped stem or branch, with its internodes so shortened that successive leaves seem almost to spring from the same point.

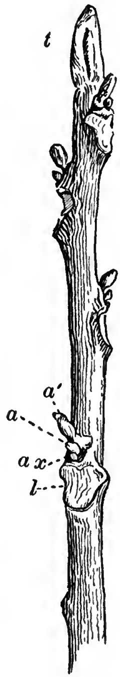
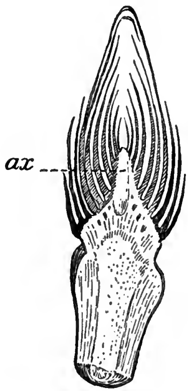


FIG. 84. — Accessory Buds of Butternut. (Reduced.)

l, leaf-scar; *ax*, axillary bud; *a*, *a′*, accessory buds; *t*, terminal bud.

136. Vernation. — Procure a considerable number of buds which are just about to burst, and others which have begun to open. Cut each across with a razor or very sharp scalpel; examine first with the magnifying glass, and then with the lowest power of the microscope. Pick to pieces other buds of the same kinds under the magnifying glass, and report upon the manner in which the leaves are packed away.

The arrangement of leaves in the bud is called *vernation;* some of the principal modes are shown in Fig. 86.



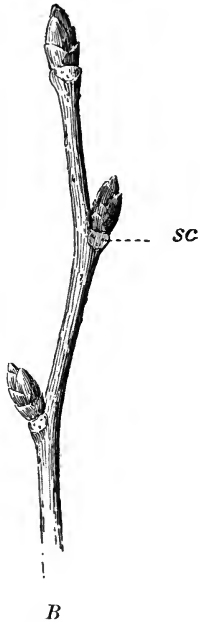


FIG. 85. — A slowly grown Twig of Cherry, 3 inches long and about ten years old.

The pointed bud *l* is a leaf-bud; the more obtuse accessory buds *f*, *f* are flower-buds.

FIG. 86.

B, a twig of European elm; *A*, a longitudinal section of the buds of *B* (considerably magnified); *ax*, the axis of the bud, which will elongate into a shoot; *sc*, leaf-scars.

In the cherry the two halves of the leaf are folded together flat, with the under surfaces outward; in the walnut the separate *leaflets*, or parts of the leaf, are folded flat and then grouped into a sort of cone; in the snowball each half of the leaf is plaited in a somewhat fan-like manner, and the edges of the two halves are then brought round so as to meet; in the lady's mantle the fan-like plaiting is very distinct; in the wood sorrel each leaflet

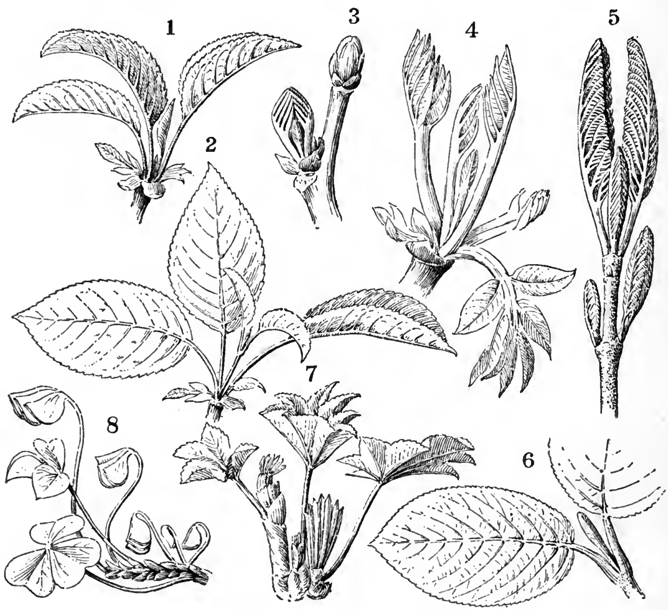
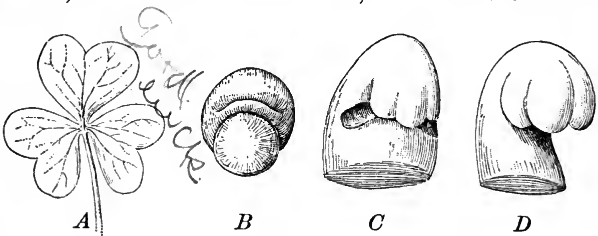


FIG. 87, I.—Types of Vernation.
1, 2, Cherry; 3, 4, European walnut; 5, 6, snowball; 7, lady's mantle; 8, oxalis.

is folded smoothly, and then the three leaflets packed closely side by side. All these modes of vernation and many others have received accurate descriptive names by which they are known to botanists.

137. Importance of Vernation.—The significance of vernation is best understood by considering that there are two important purposes to be served; the leaves must be stowed as closely as possible in the bud, and upon beginning to open they must be protected from too great heat and dryness until they have reached a certain degree of firmness. It may be inferred from Fig. 87, I, that it is common for very young leaves to stand vertically. This protects them considerably from the scorching effect of the sun at the hottest part of the day. Many young leaves, as, for instance, those of the silver-leafed poplar, the pear, the beech, and the mountain ash, are sheltered and pro-



A B C D

FIG. 87, II. — Development of an Oxalis Leaf.

A, full-grown leaf; *B*, rudimentary leaf, the leaflets not yet evident; *C*, more advanced stage, the leaflets appearing; *D*, a still more advanced stage; *B*, *C*, and *D*, considerably magnified.

tected from the attacks of small insects by a coating of wool or down, which they afterwards lose. Those of the tulip tree are enclosed for a little time in thin pouches, which serve as bud-scales, and thus entirely shielded from direct contact with the outside air (see Sect. 117).

138. Dormant Buds. — Generally some of the buds on a branch remain undeveloped in the spring, when the other buds are beginning to grow, and this inactive condition may last for many seasons. Finally the bud may die, or some injury to the tree may destroy so many other buds as to leave the dormant ones an extra supply of food, and this, with other causes, may force them to develop and to grow into branches.

Sometimes the tree altogether fails to produce buds at places where they would regularly occur. In the lilac the terminal bud usually fails to appear, and the result is constant forking of the branches.

139. Adventitious Buds. — Buds which occur in irregular places, that is, not terminal nor in or near the axils of leaves, are called *adventitious buds;* they may spring from the roots, as in the silver-leafed poplar, or from the sides of the trunk, as in our American elm. In many trees, for instance willows and maples, they are sure to appear after the trees have been cut back. Willows are thus cut back or *pollarded*, as shown in Plate II, in order to cause them to produce a large crop of slender twigs suitable for basket-making.

Leaves rarely produce buds, but a few kinds do so when they are injured. Those of the bryophyllum, a plant allied to the garden live-for-ever, when they are removed from the plant while they are still green and fresh, almost always send out buds from the margin. These do not appear at random but are borne at the notches in the leaf-margin and are accompanied almost from the first by minute roots.

Pin up a bryophyllum leaf on the wall of the room or lay it on the surface of moist earth, and follow, day by day, the formation and development of the buds which it may produce.

This plant seems to rely largely upon leaf-budding to reproduce itself, for in a moderately cool climate it rarely flowers or seeds, but drops its living leaves freely, and from each such leaf one or several new plants may be produced.

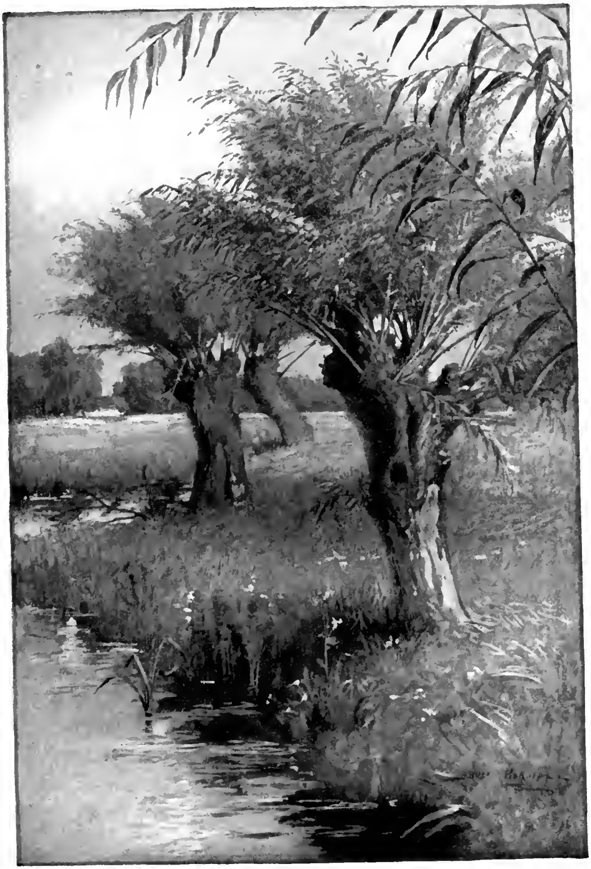


Plate II. — Pollarded Willows

140. Review Summary of Chapter VIII.

- Buds
  - Coverings . . . .
  - Contents . . .
    - leaf-buds . . . .
    - flower-buds . . . .
    - mixed buds . . . .

- Classes of buds as regards position . . .
  - regular
  - irregular . . . .

Make a sketch of Fig. 82 as it looked in June of the same summer; also as it would look the following June. Sketch the twigs of Fig. 30 and Fig. 86 as seen one year later.

CHAPTER IX

LEAVES

141. The Elm Leaf. — Sketch the leafy twig of elm that is supplied to you.[1]

Report on the following points:

(*a*) How many rows of leaves?

(*b*) How much overlapping of leaves when the twig is held with the upper sides of the leaves toward you? Can you suggest a reason for this? Are the spaces between the edges of the leaves large or small compared with the leaves themselves?

Pull off a single leaf and make a very careful sketch of its under surface, about natural size. Label the broad expanded part the *blade*, and the stalk by which it is attached to the twig, *leaf-stalk* or *petiole.*

Study the outline of the leaf and answer these questions:

(*a*) What is the shape of the leaf taken as a whole? (See Fig. 88.) Is the leaf *bilaterally symmetrical, i.e.*, is there a middle line running through it lengthwise, along which it could be so folded that the two sides would precisely coincide?

(*b*) What is the shape of the tip of the leaf? (See Fig. 89.)

(*c*) Shape of the base of the leaf? (See Fig. 90.)

(*d*) Outline of the margin of the leaf? (See Fig. 93.)

Notice that the leaf is traversed lengthwise by a strong *midrib* and that many so-called *veins* run from this to the margin. Are

[1] Any elm will answer the purpose. Young strong shoots which extend horizontally are best, since in these leaves are most fully developed and their distribution along the twig appears most clearly. Other good kinds of leaves with which to begin the study, if elm leaves are not available, are those of beech, oak, willow, peach, cherry, apple. Most of the statements and directions above given would apply to any of the leaves just enumerated. If this chapter is reached too early in the season to admit of suitable material being procured for the study of leaf arrangement, that topic may be omitted until the leaves of forest trees have sufficiently matured.

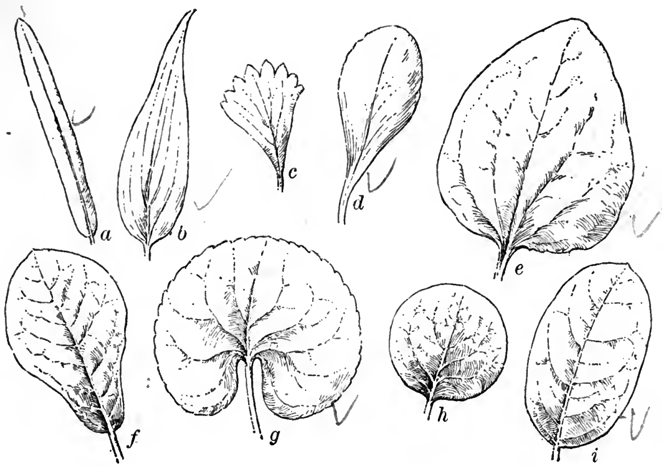


FIG. 88.—General Outline of Leaves.

a, linear; *b*, lanceolate; *c*, wedge-shaped; *d*, spatulate; *e*, ovate; *f*, obovate; *g*, kidney-shaped; *h*, orbicular; *i*, elliptical.

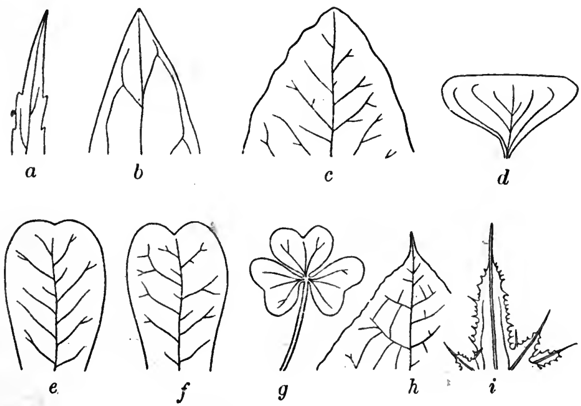


FIG. 89.—Tips of Leaves.

a, acuminate or taper-pointed; *b*, acute; *c*, obtuse; *d*, truncate; *e*, retuse; *f*, emarginate or notched; *g* (end leaflet), obcordate; *h*, cuspidate,—the point sharp and rigid; *i*, mucronate,—the point merely a prolongation of the midrib.

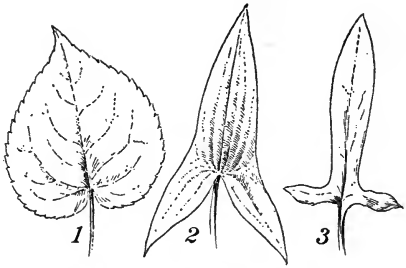


FIG. 90. — Shapes of Bases of Leaves.

1, heart-shaped (unsymmetrically); 2, arrow-shaped; 3, halberd-shaped.

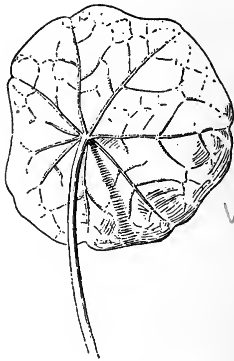


FIG. 91. — Peltate Leaf of Tropæolum.

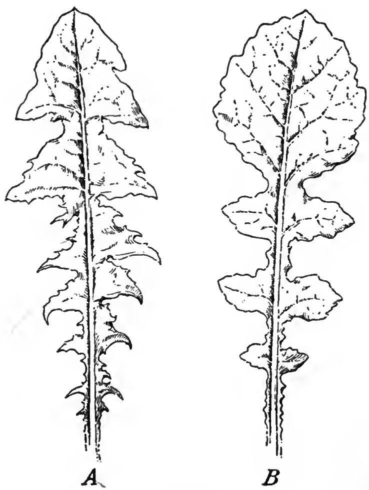


FIG. 92.

A, runcinate leaf of dandelion; *B*, lyrate leaf.

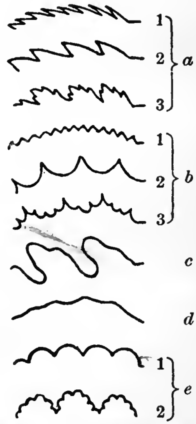


FIG. 93. — Shapes of Margins of Leaves.

a (1), finely serrate; (2), coarsely serrate; (3), doubly serrate. *b* (1), finely dentate; (2), sinuate dentate; (3), doubly dentate. *c*, deeply sinuate. *d*, wavy. *e* (1), crenate or scalloped; (2), doubly crenate.

these veins parallel? Hold the leaf up towards the light and see how the main veins are connected by smaller *veinlets*. Examine with your glass the leaf as held to the light and make a careful sketch of portions of one or two veins and the intersecting veinlets. How is the course of the veins shown on the upper surface of the leaf?

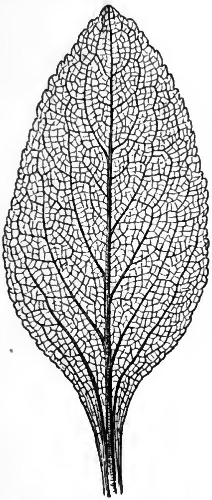


FIG. 94.—Netted Veining (pinnate) in the Leaf of the Foxglove.

Examine both surfaces of the leaf with the glass and look for hairs distributed on the surfaces. Describe the manner in which the hairs are arranged.

The various forms of leaves are classed and described by botanists with great minuteness,[1] not simply for the study of leaves themselves, but also because in classifying and describing plants the characteristic forms of the leaves of many kinds of plants form a very simple and ready means of distinguishing them from each other and identifying them. The student is not expected to learn the names of the several shapes of leaves as a whole or of their bases, tips, or margins, except in those cases in which he needs to use and apply them.

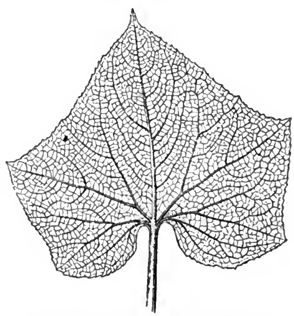


FIG. 95.—Netted Veining (palmate) in Leaf of Melon.

Many of the words used to describe the shapes of leaves are equally applicable to the leaf-like parts of flowers.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 623–637.

142. The Maple Leaf. — Sketch the leafy twig.

Are the leaves arranged in rows like those of the elm? How are they arranged?

How are the petioles distorted from their natural positions to bring the proper surface of the leaf upward toward the light?

Do the edges of these leaves show larger spaces between them than the elm leaves did, *i.e.*, would a spray of maple intercept the sunlight more or less perfectly than a spray of elm? Pull off a single leaf and sketch its lower surface, about natural size.

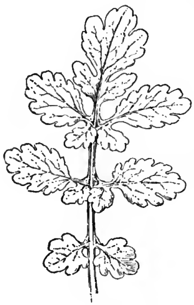


FIG. 96.—Pinnately Divided Leaf of Celandine.

The blade of the leaf is discontinuous, consisting of several portions between which are spaces in which one part of the blade has been developed.

Of the two main parts whose names have already been learned (blade and petiole), which is more developed in the maple than in the elm leaf?

Describe:

(*a*) The shape of the maple leaf as a whole. To settle this, place the leaf on paper, mark the positions of the extreme points and connect these by a smooth line.

(*b*) Its outline as to main divisions: of what kind and how many.

(*c*) The detailed outline of the margin (Fig. 93).

Compare the mode of veining or venation of the elm and the maple leaf by making a diagram of each.

These leaves agree in being *netted-veined; i.e.*, in having veinlets that join each other at many angles, so as to form a sort of delicate lace-work, like Figs. 94 and 95.

They differ, however, in the arrangement of the principal veins. Such a leaf as that of the elm is said to be feather-veined, or *pinnately veined.*

The maple leaf, or any leaf with closely similar venation, is said to be *palmately veined*. Describe the difference between the two plans of venation.

143. Relation of Venation to Shape of Leaves. —As soon as the student begins to observe leaves somewhat widely, he can hardly fail to notice that there is a general relation between the plan of venation and the shape of the leaf. How may this relation be stated? In most cases the principal veins follow at the outset a pretty straight course, a fact for which the student ought to be able to give a reason after he has performed Exp. XXXII.

On the whole, the arrangement of the veins seems to be such as to stiffen the leaf most in the parts that need

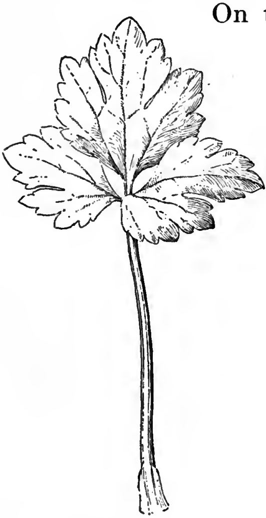


FIG. 97. — Palmately Divided Leaf of Buttercup.

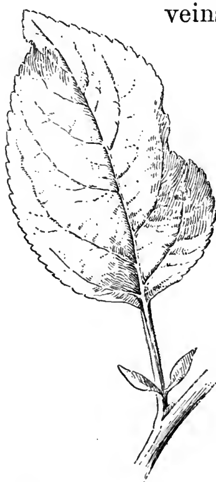


FIG. 98. — Leaf of Apple, with Stipules.

FIG. 99. — Leaf of Pansy, with Leaf-Like Stipules.

most support, and to reach the region near the margin by as short a course as possible from the end of the petiole.

144. Stipules. — Although they are absent from many leaves, and disappear early from others, *stipules* form a part of what the botanist regards as an ideal or model leaf.[1] When present they are sometimes found as little

[1] Unless the elm twigs used in the previous study were cut soon after the unfolding of the leaves in spring, the stipules may not have been left in any recognizable shape.

bristle-shaped objects at the base of the leaf, as in the apple leaf (Fig. 98), sometimes as leaf-like bodies, for example in the pansy (Fig. 99), and in many other forms, one of which is that of spinous appendages, as shown in the common locust (Fig. 103).

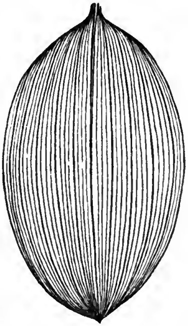


FIG. 100. — Parallel-Veined Leaf of Solomon's Seal.

145. Parallel-Veined Leaves. — The leaves of many great groups of plants, such as the lilies, the sedges, and the grasses, are commonly *parallel-veined*, that is, with the veins running nearly parallel, lengthwise through the blade, as shown in Fig. 100, or with parallel veins proceeding from a midrib and thence extending to the margin, as shown in Fig. 101.

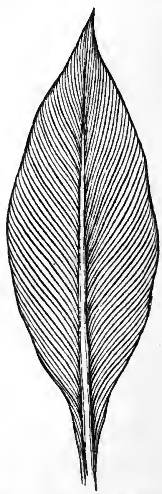


FIG. 101. — Parallel Veining in Canna. Veins running from midrib to margin.

146. Occurrence of Netted Veining and of Parallel Veining. — The student has already, in his experiments on germination, had an opportunity to observe the difference in mode of veining between the leaves of some dicotyledonous plants and those of monocotyledonous plants. This difference is general throughout these great groups of flowering plants. What is the difference?

The polycotyledonous pines, spruces, and other coniferous trees have leaves with but a single vein, or two or three parallel ones, but in their case the veining could hardly be other than parallel, since the needle-like leaves are so narrow that no veins of any considerable length could exist except in a position lengthwise of the leaf.

The fact that a certain plan of venation is found mainly in plants with a particular mode of germination, of stem structure, and of arrangement of floral parts, is but one of the frequent cases in botany in which the structures of plants are correlated in a way which it is not easy to explain.

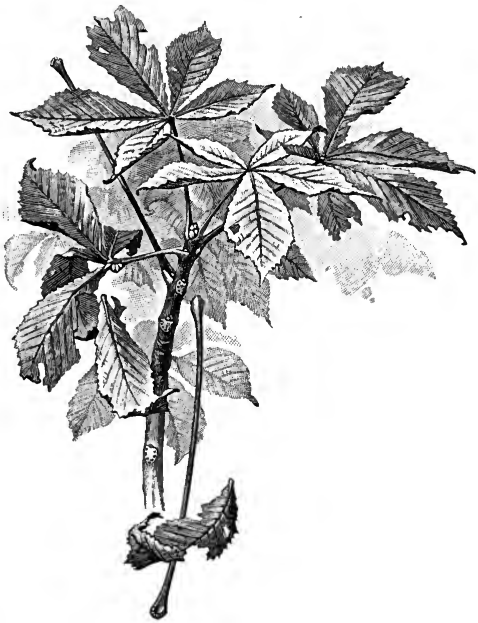


FIG. 102. — The Fall of the Horse-Chestnut Leaf.

No one knows why plants with two cotyledons should have netted-veined leaves, but many such facts as this are familiar to every botanist.

147. Simple and Compound Leaves. — The leaves so far studied are *simple leaves*, that is, leaves of which the blades are more or less entirely united into one piece. But while in the elm the margin is cut in only a little way, in some maples it is deeply cut in toward the bases of the veins. In some leaves the gaps between the adjacent portions extend all the way down to the petiole (in palmately veined leaves) or to the midrib (in pinnately veined ones). Such divided leaves are shown in Figs. 96 and 97.

In still other leaves, known as *compound leaves*, the petiole, as shown in Fig. 102 (*palmately compound*), or the midrib, as shown in Fig. 103 (*pinnately compound*), bears what look to be separate leaves. These differ in their nature and mode of origin from the portions of the blade of a divided leaf. One result of this difference appears in the fact that some time before the whole leaf is ready to fall from the tree or other plant in autumn, the separate portions or leaflets of a compound leaf are seen to be jointed at their attachments, just as whole leaves are to the part of the stem from which they grow. In Fig. 102 the horse-chestnut leaf is shown at the time of falling, with some of the leaflets already disjointed.

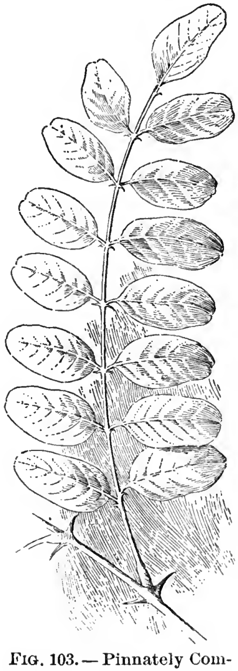


Fig. 103. — Pinnately Compound Leaf of Locust, with Spines for Stipules.

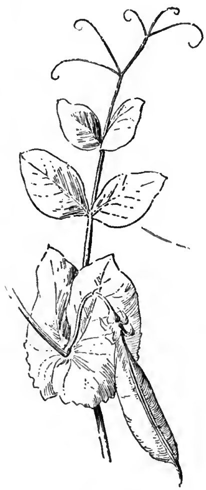


Fig. 104. — Pinnately Compound Leaf of Pea. A tendril takes the place of a terminal leaflet.

That a compound leaf, in spite of the joints of the separate leaflets, is really only one leaf is shown: (1) by the absence of buds in the axils of leaflets (see Fig. 82); (2) by the arrangement of the blades of the leaflets horizontally, without any twist in their individual leaf-stalks; (3) by the fact that their arrangement on the midrib does not follow any of the systems of leaf arrangement on the stem (Sect. 149). If each leaflet of a compound leaf should itself become compound, the result would be to produce a *twice compound* leaf. Fig. 113 shows that of an acacia. What would be the appearance of a thrice compound leaf?

148. Review Summary of Leaves.[1]

Parts of a model leaf	1. 2. 3.
Classes of netted-veined leaves	1. 2.
Classes of parallel-veined leaves	1. 2.
Relation of venation to number of cotyledons	
Compound leaves; —types, dependent on arrangement of leaflets	1. 2.
Once, twice, or three times compound	

[1] Illustrate by sketches if possible.

CHAPTER X

LEAF ARRANGEMENT FOR EXPOSURE TO SUN AND AIR; MOVEMENTS OF LEAVES AND SHOOTS

149. Leaf Arrangement.[1] — As has been learned from the study of the leafy twigs examined, leaves are quite generally arranged so as to secure the best possible exposure to the sun and air. This, in the vertical shoots of the elm, the oak (Fig. 105), the apple, beech, and other alternate-leaved trees, is not inconsistent with their spiral arrangement of the leaves around the stem. In horizontal twigs and branches of the elm, the beech (Fig. 106), the chestnut, the linden, and many other trees and shrubs, the desired effect is secured by the arrangement of all the leaves in two flat rows, one on each side of the twig.

FIG. 105. — Leaf Arrangement of the Oak.

FIG. 106. — Leaf Arrangement of European Beech.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 396–424.

Plate III. — Exposure to Sunlight, Japanese Ivy

The rows are produced, as it is easy to see on examining such a leafy twig, by a twisting about of the petioles. The adjustment in many opposite-leaved trees and shrubs consists in having each pair of leaves cover the spaces between the pair below it, and sometimes in the lengthening of the lower petioles so as to bring the blades of the lower leaves outside those of the upper leaves. Examination of Figs. 107 and 108 will make the matter clear.

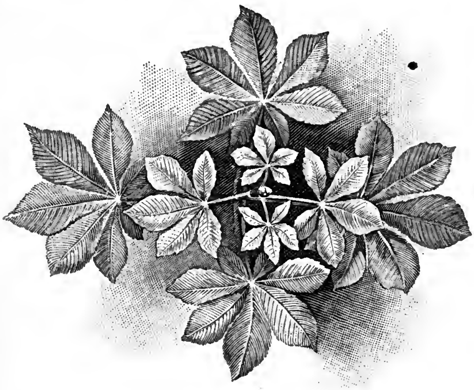


FIG. 107.—Leaf Arrangement of Horse-Chestnut on Vertical Shoots (top view).

The student should not fail to study the leafage of several trees of different kinds on the growing tree itself, and in climbers on walls (Plate III), and to notice how circumstances modify the position of the leaves. Maple leaves, for example, on the ends of the branches are arranged much

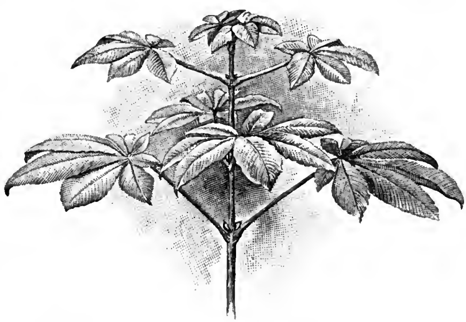


FIG. 108.—Leaf Arrangement of Horse-Chestnut on Vertical Shoots (side view).

like those of the horse-chestnut, but they are found to be arranged more nearly flatwise along the inner portions of the branches, that is, the portions nearer the tree. Figs. 109 and 110 show the remarkable difference in arrangement in different branches of the Deutzia, and equally interesting modifications may be found in alternate-leaved trees, such as the elm and the cherry.

FIG. 109.—Opposite Leaves of Deutzia[1] (from the same shrub as Fig. 110), as arranged on a Horizontal Branch.

150. Leaf-Mosaics.—In very many cases the leaves at the end of a shoot are so arranged as to form a pretty symmetrical pattern, as in the horse-chestnut (Fig. 107). When this is sufficiently regular, usually with the space between the leaves a good deal smaller than the areas of the leaves themselves, it is called a *leaf-mosaic* (Fig. 111). Many of the most interesting leaf-groups of this sort (as

[1] *Deutzia crenata.*

in the figure above mentioned) are found in the so-called root-leaves of plants. Good examples of these are the dandelion, chicory, fall dandelion, thistle, hawkweed, pyrola, plantain. How are the leaves of these plants kept from shading each other?

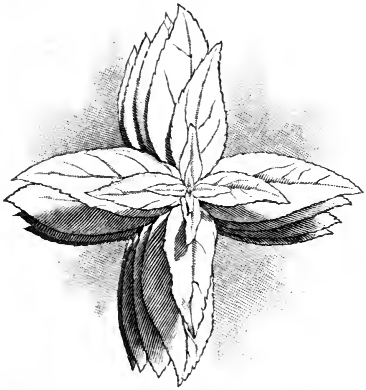


FIG. 110. — Opposite Leaves of Deutzia, as arranged on a Vertical Branch.

151. Much-Divided Leaves. — Not infrequently leaves are cut into slender fringe-like divisions, as in the carrot, tansy, southernwood, wormwood, yarrow, dog-fennel, cypress-vine, and many other common plants. This kind of leaf seems to be adapted to offer considerable surface to the sun without cutting off too much light from other leaves underneath. Such a leaf is in much less danger of being torn by severe winds than are broader ones with undivided margins. The same purposes are served by compound leaves with very many small leaflets, such as those of the honey-locust, mimosa acacia (Fig. 113), and other trees and shrubs of the pea family. What kind of shade is produced by a horse-chestnut or a maple tree compared with that of a honey-locust or an acacia?

FIG. 111. — Leaf-Mosaic of a Campanula.

152. Daily Movements of Leaves. — Many compound leaves have the power of changing the position of their leaflets to accommodate themselves to varying conditions of light and temperature. Some plants have the power of directing the leaves or leaflets edgewise towards the sun during the hottest parts of the day, allowing them to extend their surfaces more nearly in a horizontal direction during the cooler hours.

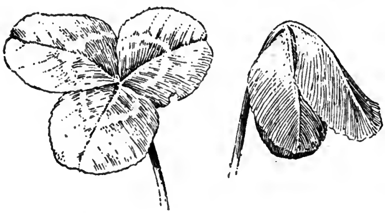


FIG. 112. — A Leaf of Red Clover. At the left, leaf by day; at the right, the same leaf asleep at night.

The so-called "sleep" of plants has long been known, but this subject has been most carefully studied rather recently. The wood sorrel, or oxalis, the common bean, clovers, and the locust tree are some of the most familiar of the plants whose leaves assume decidedly different positions at night from those which they occupy during the day. Sometimes the leaflets rise at night, and in many instances they droop, as in the red clover (Fig. 112) and the acacia (Fig. 113). One useful purpose, at any rate, that is served by the leaf's taking the nocturnal position is protection from frost. It has been proved experimentally that when part of the leaves on a plant are prevented from assuming the folded position, while others are allowed to do so, and the plant is then exposed during a frosty night, the folded ones may escape while the others are killed. Since many plants in tropical climates fold their leaves at night, it is certain that this movement has other purposes than protection from frost, and probably there is much yet to be learned about the meaning and importance of leaf-movements.

153. Cause of Sleep-Movements. — The student may very naturally inquire whether the change to the nocturnal position is brought about by the change from light to darkness or whether it depends rather upon the time of day. It will be interesting to try an experiment in regard to this.

EXPERIMENT XXVI

Remove a pot containing an oxalis from a sunny window to a dark closet, at about the same temperature, and note at intervals of five minutes the condition of its leaves for half an hour or more.

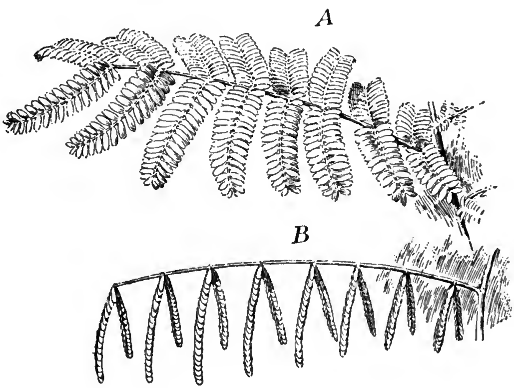


Fig. 113. — A Leaf of Acacia.
A, as seen by day; *B*, the same leaf asleep at night.

154. Structure of the Parts which cause Leaf-Motions. — In a great number of cases the daily movements of leaves are produced by special organs at the bases of the leaf-stalks. These cushion-like organs, called *pulvini* (Fig. 114), are composed mainly of parenchymatous tissue

(Sect. 106), which contains much water. It is impossible fully to explain in simple language the way in which the cells of the pulvini act, but in a general way it may be said that changes in the light to which the plant is exposed cause rather prompt changes in the amount of water in the cells in one portion or other of the pulvinus. If the cells on one side are filled fuller of water than usual, that side of the pulvinus will be expanded and make the leaf-stalk bend toward the opposite side. The promptness of these movements is no doubt in considerable measure due to the fact that in the pulvini (as in many other parts of plants) the protoplasm of adjacent cells is connected. Delicate threads of protoplasm extend through the cell-walls, making the whole tissue a living web, so that any suitable stimulus or excitant which acts on one part of the organ will soon affect the whole organ.

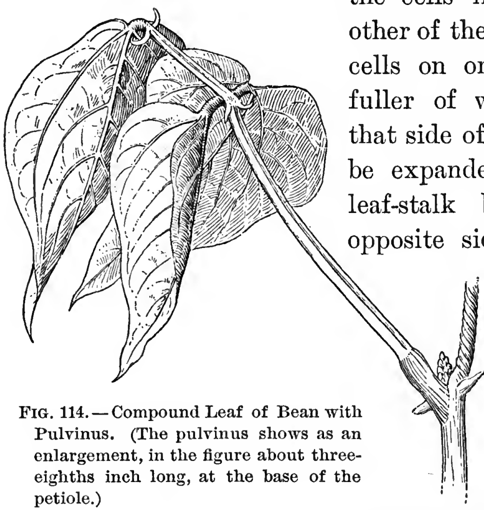


Fig. 114. — Compound Leaf of Bean with Pulvinus. (The pulvinus shows as an enlargement, in the figure about three-eighths inch long, at the base of the petiole.)

155. Vertically Placed Leaves. — Very many leaves, like those of the iris (Fig. 44), always keep their principal surfaces nearly vertical, thus receiving the morning and evening sun upon their faces, and the noonday sun (which is so intense as to injure them when received full on the surface) upon their edges. This adjustment is most perfect in the compass-plant of the prairies of the Mississippi basin. Its leaves stand very nearly upright, many with

A B

Fig. 115.—Leaves standing nearly Vertical in Compass-Plant (*Silphium laciniatum*). *A*, view from east or west; *B*, from north or south.

their edges just about north and south (Fig. 115), so that the rays of the midsummer sun will, during every bright day, strike the leaf-surfaces nearly at right angles during a considerable portion of the forenoon and afternoon, while at midday only the edge of each leaf is exposed to the sun.

156. Movements of Leaves and Stems toward or away from Light (Heliotropic Movements). — The student doubtless learned from his experiments with seedling plants that their stems tend to seek light. The whole plant above ground usually bends toward the quarter from which the strongest light comes. Such movements are called *heliotropic* from two Greek words which mean turning toward the sun. How do the plants in a window behave with reference to the light?

EXPERIMENT XXVII

How do Young Shoots of English Ivy bend with Reference to Light? — Place a thrifty potted plant of English ivy before a small window, *e.g.*, an ordinary cellar window, or in a large covered box, painted dull black within and open only on the side toward a south window. After some weeks note the position of the tips of the shoots. Explain the use of their movements to the plant.

157. Positive and Negative Heliotropic Movements; how produced. — Plants may bend either toward or away from the strongest light. In the former case they are said to show *positive heliotropism*, in the latter *negative heliotropism*. In both cases the movement is produced by unequal growth, brought about by the unequal lighting of different sides of the stem. If the less strongly lighted side grows faster, what kind of heliotropism results? If the more strongly lighted side grows faster, what kind of heliotropism results? How would a plant behave if placed on a revolving table before a window and slowly turned during the hours of daylight?

158. Review Summary of Chapter X.

Leaf arrangement . . .	For vertical twigs	
	For horizontal twigs . . .	
Movements of leaves . .	Apparatus for	
	Causes of	
	Uses of	
Compass-plants		
Heliotropic bending of stems	Positive	
	Negative	

CHAPTER XI

MINUTE STRUCTURE OF LEAVES; FUNCTIONS OF LEAVES

159. Leaf of Lily. — A good kind of leaf with which to begin the study of the microscopical structure of leaves in general is that of the lily.[1]

160. Cross-Section of Lily Leaf. — The student should first examine with the microscope a cross-section of the leaf, that is, a very thin slice, taken at right angles to the upper and under surfaces and to the veins. This will show:

(*a*) The upper epidermis of the leaf, a thin, nearly transparent membrane.

(*b*) The intermediate tissues.

(*c*) The lower epidermis.

Use a power of from 100 to 200 diameters. In order to ascertain the relations of the parts, and to get their names, consult Fig. 116. Your section is by no means exactly like the figure; sketch it. Label properly all the parts shown in your sketch.

Are any differences noticeable between the upper and the lower epidermis? Between the layers of cells immediately adjacent to each?

161. Under Surface of Lily Leaf. — Examine with a power of 200 or more diameters the outer surface of a piece of epidermis from the lower side of the leaf.[2] Sketch carefully, comparing your sketch with Figs. 117 and 118, and labeling it to agree with those figures.

Examine another piece from the upper surface; sketch it.

How does the number of *stomata* in the two cases compare?

[1] Any kind of lily will answer.

[2] The epidermis may be started with a sharp knife, then peeled off with small forceps, and mounted in water for microscopical examination.

Take measurements from the last three sketches with a scale and, knowing what magnifying power was used, answer these questions[1]:

(*a*) How thick is the epidermis?

(*b*) What is the length and the breadth of the epidermal cells?

(*c*) What is the average size of the pulp-cells?

A *stoma* is a microscopic pore or slit in the epidermis. It is bounded and opened and shut by guard-cells (Fig. 118, *g*), usually two in number. These are generally

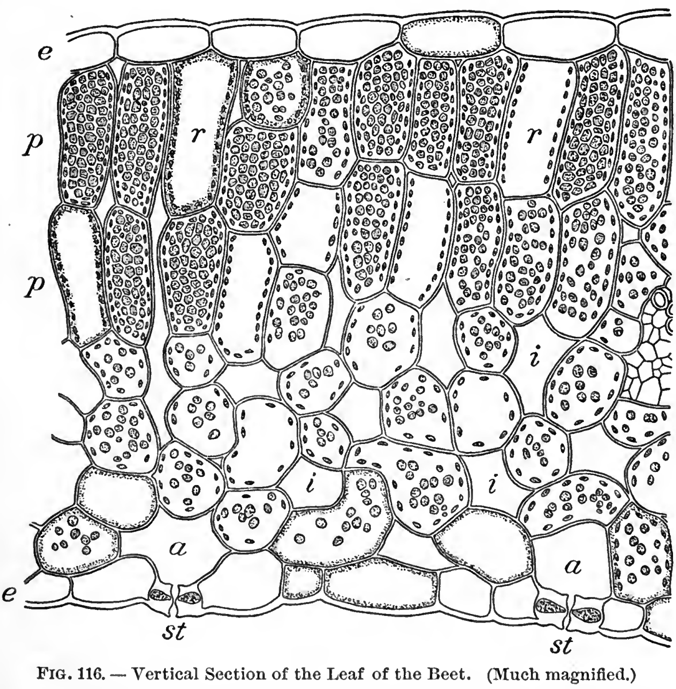


FIG. 116. — Vertical Section of the Leaf of the Beet. (Much magnified.)

e, epidermis; *p*, palisade-cells (and similar elongated cells); *r*, cells filled with red cell sap; *i*, intercellular spaces; *a*, air spaces communicating with the stomata; *st*, stomata, or breathing pores.

[1] The teacher may measure the size with the *camera lucida*.

somewhat kidney-shaped and become more or less curved as they are fuller or less full of water (see Sect. 170).

162. Calculation of Number of Stomata per Unit of Area. — In order to get a fairly exact idea of the number of stomata on a unit of leaf-surface, the most convenient plan is to make use of a photo-micrograph. The bromide enlargement No. 12 of the Tower series represents about a twenty-five-hundredth of a square inch of the lower epidermis of the cyclamen leaf, magnified until it is about fifteen inches square. Count the number of stomata on the entire photograph, then calculate the number of stomata on a square inch of the surface of this leaf. If a cyclamen plant has twelve leaves, each with an average area of six square inches, calculate the number of stomata of the lower epidermis of all the leaves taken together.

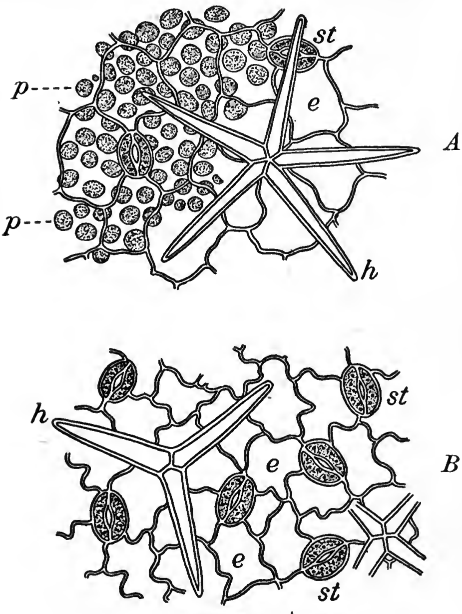


FIG. 117. — Epidermis of Leaf of Althæa. (Much magnified.)

A, from upper surface; *B*, from lower surface. *h*, star-shaped compound hairs; *st*, stomata; *p*, upper ends of palisade-cells, seen through the epidermis; *e*, cells of epidermis.

In the case of an apple tree, where the epidermis of the lower surface of the leaf contains about 24,000 stomata to the square inch, or the black walnut, with nearly 300,000 to the square inch, the total number on a tree is inconceivably large.

163. Uses of the Parts examined. — It will be most convenient to discuss the uses of the parts of the leaf a little later, but it will make matters simpler to state at once that the epidermis serves as a mechanical protection to the parts beneath and prevents excessive evaporation, that the palisade-cells (which it may not be easy to make out very clearly in a roughly prepared section) hold large quantities of the green coloring matter of the leaf in a position where it can receive enough but not too much sunlight, and the cells of the spongy parenchyma share the work of the palisade-cells, besides evaporating much water. The stomata admit air to the interior of the leaf (where the air spaces

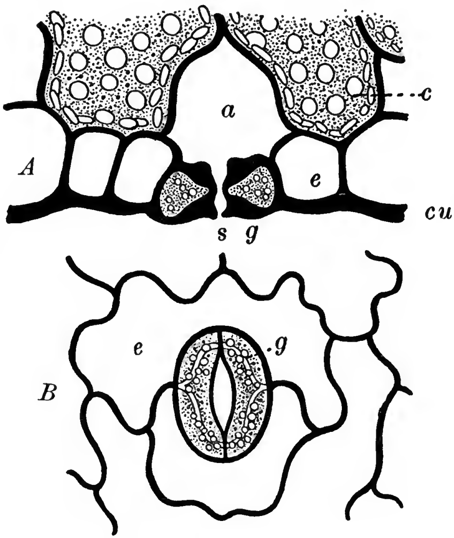


FIG. 118. — A Stoma of Thyme. (Greatly magnified.)
A, section at right angles to surface of leaf; *B*, surface view of stoma. *cu*, cuticle; *g*, guard-cells; *s*, stoma; *e*, epidermal cells; *a*, air chamber; *c*, cells of spongy parenchyma with grains of chlorophyll.

serve to store and to distribute it), they allow oxygen and carbonic acid gas to escape, and, above all, they regulate the evaporation of water from the plant.

164. Leaf of "India-Rubber Plant."[1] — Study with the microscope, as the lily leaf was studied, make the same set of sketches, note the differences in structure between the two leaves, and try to discover their meaning.

How does the epidermis of the two leaves compare?

Which has the larger stomata?

Which would better withstand great heat and long drought?

165. Chlorophyll as found in the Leaf. — Slice off a little of the epidermis from some such soft, pulpy leaf as

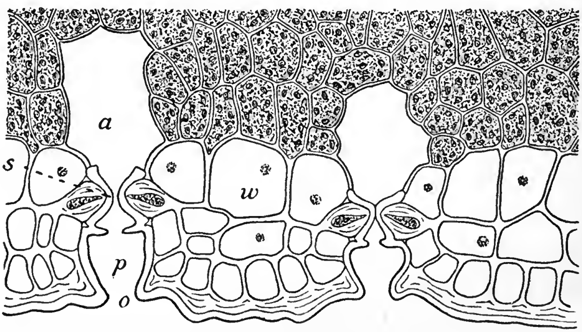


FIG. 119. — Section through Lower Epidermis of Leaf of India-Rubber Plant (*Ficus elastica*). (Magnified 330 diameters.)

o, opening of pit; *p*, pit leading to stoma; *s*, stoma, with two guard-cells; *w*, water-storage cells of epidermis; *a*, an air space; around and above the air spaces are cells of the spongy parenchyma.

that of the common field sorrel,[2] live-for-ever, or spinach; scrape from the exposed portion a very little of the green pulp; examine with the highest power attainable with your microscope, and sketch several cells.

[1] *Ficus elastica*, a kind of fig tree.

[2] *Rumex Acetosella.*

Notice that the green coloring matter is not uniformly distributed, but that it is collected into little particles called *chlorophyll bodies* (Fig. 120, *p*).

166. Woody Tissue in Leaves. — The veins of leaves consist of fibro-vascular bundles containing wood and vessels much like those of the stem of the plant. Indeed, these bundles in the leaf are continuous with those of the stem, and consist merely of portions of the latter, looking as if unraveled, which pass outward and upward from the stem into the leaf under the name of *leaf-traces*. These traverse the petiole often in a somewhat irregular fashion.

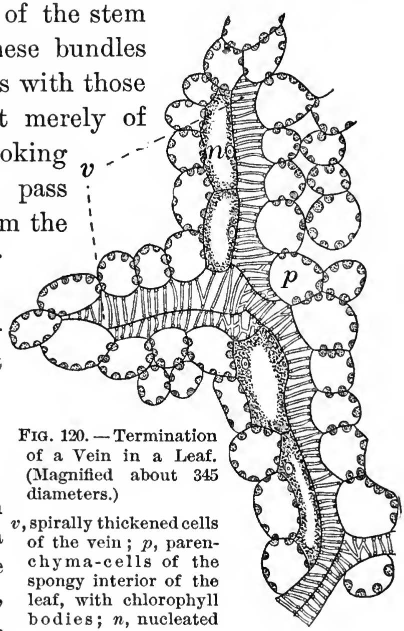


FIG. 120. — Termination of a Vein in a Leaf. (Magnified about 345 diameters.)

v, spirally thickened cells of the vein; *p*, parenchyma-cells of the spongy interior of the leaf, with chlorophyll bodies; *n*, nucleated cells.

EXPERIMENT XXVIII

Passage of Water from Stem to Leaf. — Place a freshly cut leafy shoot of some plant with large thin leaves, such as *Hydrangea hortensia*, in eosin solution for a few minutes. As soon as the leaves show a decided reddening, pull some of them off and sketch the red stains on the scars thus made. What does this show?

167. Experimental Study of Functions of Leaves. — The most interesting and profitable way in which to find out what work leaves do for the plant is by experimenting upon them. Much that relates to the uses of leaves is not readily shown in ordinary class-room experiments, but some things can readily be demonstrated in the experiments which follow.

EXPERIMENT XXIX

Transpiration. — Take two twigs or leafy shoots of any thin-leafed plant;[1] cover the cut end of each stem with a bit of grafting wax[2] to prevent evaporation from the cut surface. Put one shoot into a fruit jar, screw the top on, and leave in a warm room; put the other beside it, and allow both to remain some hours. Examine the relative appearance of the two, as regards wilting, at the end of the time.

Which shoot has lost most? Why? Has the one in the fruit jar lost any water? To answer this question, put the jar (without opening it) into a refrigerator; or, if the weather is cold, put it out of doors for a few minutes, and examine the appearance of the inside of the jar. What does this show?[3]

168. Uses of the Epidermis.[4] — The epidermis, by its toughness, tends to prevent mechanical injuries to the leaf, and after the filling up of a part of its outer portion with a corky substance it greatly diminishes the loss of water from the general surface. This process of becoming filled with cork substance, *suberin* (or a substance of similar properties known as *cutin*) is essential to the safety of leaves or of young stems which have to withstand heat and dryness. The corky or cutinized cell-wall is waterproof, while ordinary cellulose allows water

[1] Hydrangea, squash, melon, or cucumber is best; many other kinds will answer very well.

[2] Grafting wax may be bought of nurserymen or seedsmen.

[3] If the student is in doubt whether the jar filled with ordinary air might not behave in the same way, the question may be readily answered by putting a sealed jar of air into the refrigerator.

[4] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 273–362.

to soak through it with ease. Merely examining sections of the various kinds of epidermis will not give nearly as good an idea of their properties as can be obtained by studying the behavior during severe droughts of plants which have strongly cutinized surfaces and of those which have not. Fig. 121, however, may convey some notion of the difference between the two kinds of structure. In most cases, as in the india-rubber tree, the external epidermal cells (and often two or three layers of cells beneath these) are filled with water, and thus serve as reservoirs from which the outer parts of the leaf and the stem are at times supplied.

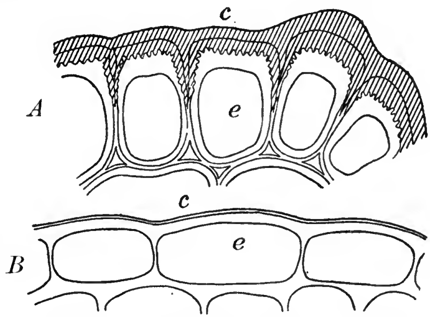


Fig. 121.—Unequal Development of Cuticle by Epidermis-Cells.

A, epidermis of Butcher's Broom (*Ruscus*); *B*, epidermis of sunflower; *c*, cuticle; *e*, epidermis-cells.

In many cases, noticeably in the cabbage, the epidermis is covered with a waxy coating, which doubtless increases the power of the leaf to retain needed moisture, and which certainly prevents rain or dew from covering the leaf-surfaces, especially the lower surfaces, so as to hinder the operation of the stomata. Many common plants, like the meadow rue and the nasturtium, possess this power to shed water to such a degree that the under surface of the leaf is hardly wet at all when immersed in water. The air-bubbles on such leaves give them a silvery appearance when held under water.

169. Hairs on Leaves. — Many kinds of leaves are more or less hairy or downy, as those of the mullein, the "mullein pink," many cinquefoils, and other common plants. In some instances this hairiness may be a protection against snails or other small leaf-eating animals, but in other cases it seems to be pretty clear that the woolliness (so often confined to the under surface) is to lessen the loss of water through the stomata. The Labrador tea is an excellent example of a plant, with a densely woolly coating on the lower surface of the leaf. The leaves, too, are partly rolled up (see Fig. 224), with the upper surface outward, so as to give the lower surface a sort of deeply grooved form, and on the lower surface all of the stomata are placed. This plant, like some others with the same characteristics, ranges far north into regions where the temperature, even during summer, often falls so low that absorption of water by the roots ceases, since it has been shown that this nearly stops a little above the freezing point of water (see Exp. XVII). Exposed to cold, dry winds, the plant would then often be killed by complete drying if it were not for the protection afforded by the woolly, channeled under surfaces of the leaves.[1]

170. Operation of the Stomata. — The stomata serve to admit air to the interior of the leaf, and to allow moisture, in the form of vapor, to pass out of it. They do this not in a passive way, as so many mere holes in the epidermis might, but to a considerable extent they regulate the rapidity of transpiration, opening more widely in damp weather and closing in dry weather. The opening is

[1] This adaptation is sufficiently interesting for class study.

Plate IV. — A Cypress Swamp

caused by each of the guard-cells bending into a more kidney-like form than usual, and the closing by a straightening out of the guard-cells. The under side of the leaf, free from palisade-cells, abounding in intercellular spaces, and pretty well protected from becoming covered with rain or dew, is especially adapted for the working of the stomata, and accordingly we usually find them in much greater numbers on the lower surface. On the other hand, the little flowerless plants known as liverworts, which lie prostrate on the ground, have their stomata on the upper surface, and so do the leaves of pond lilies, which lie flat on the water. In those leaves which stand with their edges nearly vertical, the stomata are distributed somewhat equally on both surfaces. Stomata occur in the epidermis of young stems, being replaced later by the lenticels. Those plants which, like the cacti, have no ordinary leaves, transpire through the stomata scattered over their general surfaces.

The health of the plant depends largely on the proper working condition of the stomata, and one reason why plants in cities often fail to thrive is that the stomata become choked with dust and soot. In some plants, as the oleander, provision is made for the exclusion of dust by a fringe of hairs about the opening of each stoma. If the stomata were to become filled with water, their activity would cease until they were freed from it; hence many plants have their leaves, especially the under surfaces, protected by a coating of wax which sheds water.

171. Measurement of Transpiration. — We have already proved that water is lost by the leaves, but it is worth while to perform a careful experiment to reduce our knowledge to an exact form, to learn how much water a given plant transpires under certain conditions. It is also desirable to find out whether different kinds of plants transpire alike, and what changes in the temperature, the dampness of the air, the brightness of the light, to which a plant is exposed, have to do with its transpiration. Another experiment will show whether both sides of a leaf transpire alike.

EXPERIMENT XXX

Amount of Water lost by Transpiration. — Procure a thrifty hydrangea[1] and a small "india-rubber plant,"[2] each growing in a small flower-pot, and with the number of square inches of leaf-surface in the two plants not too widely different. Calculate the area of the leaf-surface for each plant, by dividing the surface of a piece of tracing cloth into a series of squares one-half inch on a side, holding an average leaf of each plant against this and counting the number of squares and parts of squares covered by the leaf. Or weigh a square inch of tinfoil on a very delicate balance, cut out a piece of the same kind of tinfoil of the size of an average leaf, weigh this and calculate the leaf-area from the two weights. This area, multiplied by the number of leaves for each plant, will give approximately the total evaporating surface for each.

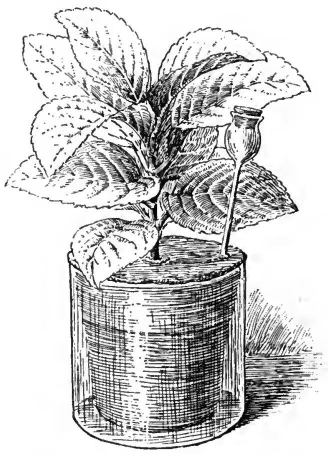


FIG. 122. — A Hydrangea potted in a Battery Jar for Exp. XXX.

Transfer each plant to a glass battery jar of suitable size. Cover

[1] The common species of the greenhouses, *Hydrangea Hortensia*.
[2] This is really a fig, *Ficus elastica*.

the jar with a piece of sheet lead, slit to admit the stem of the plant, invert the jar and seal the lead to the glass with a hot mixture of beeswax and rosin. Seal up the slit and the opening about the stem with grafting wax. A thistle-tube, such as is used by chemists, is also to be inserted, as shown in Fig. 122.[1] The mouth of this may be kept corked when the tube is not in use for watering.

Water each plant moderately and weigh the plants separately on a balance that is sensitive to one-fifth gram. Record the weights, allow the plants to stand in a sunny, warm room for twenty-four hours and reweigh.

Add to each plant just the amount of water which is lost,[2] and continue the experiment in the same manner for several days so as to ascertain, if possible, the effect upon transpiration of varying amounts of water in the atmosphere.

Calculate the average loss per 100 square inches of leaf-surface for each plant throughout the whole course of the experiment. Divide the greater loss by the lesser to find their ratio. Find the ratio of each plant's greatest loss per day to its least loss per day, and by comparing these ratios decide which transpires more regularly.

Try the effect of supplying very little water to each, so that the hydrangea will begin to droop, and see whether this changes the relative amount of transpiration for the two plants. Vary the conditions of the experiment for a day or two as regards temperature, and again for a day or two as regards light, and note the effect upon the amount of transpiration.

The structure of the fig (India-rubber plant) leaf has already been studied. That of the hydrangea is looser in texture and more like the leaf of the lily or the beet (Fig. 116).

What light does the structure throw on the results of the preceding experiment?

[1] It will be much more convenient to tie the hydrangea if one has been chosen that has but a single main stem. Instead of the hydrangea, the common cineraria, *Senecio cruentus*, does very well.

[2] The addition of known amounts of water may be made most conveniently by measuring it in a cylindrical graduate.

EXPERIMENT XXXI

Through which Side of a Leaf of the India-Rubber Plant does Transpiration occur? — The student may already have found (Sect. 164) that there are no stomata on the upper surface of the fig leaf which he studied. That fact makes this leaf an excellent one by means of which to study the relation of stomata to transpiration.

Take two large, sound rubber-plant leaves, cut off pretty close to the stem of the plant. Slip over the cut end of the petiole of each leaf a piece of small rubber tubing, wire this on, leaving about half of it free, then double the free end over and wire tightly, so as to make the covering moisture-proof. Warm some vaseline or grafting wax until it is almost liquid, and spread a thin layer of it smoothly over the upper surface of one leaf and the lower surface of the other. Hang both up in a sunny place in the laboratory and watch them for a month or more.

What difference in the appearance of the two leaves becomes evident? What does the experiment prove?

172. Endurance of Drought by Plants. — Plants in a wild state have to live under extremely different conditions as regards water supply (see Chapter XXIV). Observation of growing plants during a long drought will quickly show how differently the various species of a region bear the hardships due to a scanty supply of moisture. It is still easier, however, to subject some plants to an artificial drought and watch their condition.

EXPERIMENT XXXII

Resistance to Drought. — Procure at least one plant from each of these groups:

Group I. Melon-cactus (*Echinocactus* or *Mamillaria*), prickly pear cactus.

Group II. Aloe, *Cotyledon* (often called *Echeveria*), houseleek.

Group III. Live-for-ever (*Sedum Telephium*), *Bryophyllum*, English ivy, "ivy-leafed geranium," (*Pelargonium peltatum*), or any of the fleshy-leafed begonias.

Group IV. Hydrangea (*H. Hortensia*), squash or cucumber, sunflower.

The plants should be growing in pots and well rooted. Water them well and then put them all in a warm, sunny place. Note the appearance of all the plants at the end of twenty-four hours. If any are wilting badly, water them. Keep on with the experiment, in no case watering any plant or set of plants until it has wilted a good deal. Record the observations in such a way as to show just how long a time it took each plant to begin to wilt from the time when the experiment began. If any hold out more than a month, they may afterwards be examined at intervals of a week, to save the time required for daily observations. If possible, account by the structure of the plants for some of the differences observed. Try to learn the native country of each plant used and the soil or exposure natural to it.

173. Course traversed by Water through the Leaf.—The same plan that was adopted to trace the course of water in the stem (Exp. XXI) may be followed to discover its path through the leaf.

EXPERIMENT XXXIII

Rise of Sap in Leaves. — Put the freshly cut ends of the petioles of several thin leaves of different kinds into small glasses, each containing eosin solution to the depth of one-quarter inch or more. Allow them to stand for half an hour, and examine them by holding up to the light and looking through them to see into what parts the eosin solution has risen. Allow some of the leaves to remain as much as twelve hours, and examine them again. The red-stained portions of the leaf mark the lines along which, under natural conditions, sap rises into it. Cut across (near the petiole or midrib ends) all the principal veins of some kind of large, thin leaf. Then cut off the petiole and at once stand the cut end, to which the blade is attached, in eosin solution. Repeat with another leaf and stand in water. What do the results teach?

174. Total Amount of Transpiration. — In order to prevent wilting, the rise of sap during the life of the leaf must have kept pace with the evaporation from its surface. The total amount of water that travels through the roots, stems, and leaves of most seed-plants during their lifetime is large, relative to the weight of the plant itself. During 173 days of growth a corn-plant has been found to give off nearly 31 pounds of water. During 140 days of growth a sunflower-plant gave off about 145 pounds. A grass-plant has been found to give off its own weight of water every twenty-four hours in hot, dry summer weather. This would make about $6\frac{1}{2}$ tons per acre every twenty-four hours for an ordinary grass-field, or rather over 2200 pounds of water from a field 50×150 feet, that is, not larger than a good-sized city lot. Calculations based on observations made by the Austrian forest experiment stations showed that a birch tree with 200,000 leaves, standing in open ground, transpired on hot summer days from 700 to 900 pounds, while at other times the amount of transpiration was probably not more than 18 to 20 pounds.[1]

These large amounts of water are absorbed, carried through the tissues of the plant, and then given off by the leaves because the plant-food contained in the soil-water is in a condition so diluted that great quantities of water must be taken in order to secure enough of the mineral and other substances which the plant demands from the soil. Active transpiration may also have other causes.

[1] See B. E. Fernow's discussion in Report of Division of Forestry of U. S. Department of Agriculture, 1889.

Meadow hay contains about two per cent of potash, or 2000 parts in 100,000, while the soil-water of a good soil does not contain more than one-half part in 100,000 parts. It would therefore take 4000 tons of such water to furnish the potash for one ton of hay. The water which the root-hairs take up must, however, contain far more potash than is assumed in the calculation above given, so that the amount of water actually used in the growth of a ton of hay cannot be much more than 260 tons.[1]

175. Accumulation of Mineral Matter in the Leaf. — Just as a deposit of salt is found in the bottom of a seaside pool of salt water which has been dried up by the sun, so old leaves are found to be loaded with mineral matter, left behind as the sap drawn up from the roots is evaporated through the stomata. A bonfire of leaves makes a surprisingly large heap of ashes. An abundant constituent of the ashes of burnt leaves is silica, a substance chemically the same as sand. This the plant is forced to absorb along with the potash, compounds of phosphorus, and other useful substances contained in the soil-water; but since the silica is of hardly any value to most plants, it often accumulates in the leaf as so much refuse. Lime is much more useful to the plant than silica, but a far larger quantity of it is absorbed than is needed; hence it, too, accumulates in the leaf.

176. Nutrition, Metabolism.[2] — The manufacture of the more complex plant-foods, starch, sugar, and so on, from

[1] See the article, "Water as a Factor in the Growth of Plants," by B. T. Galloway and Albert F. Woods, *Year-Book of U. S. Department of Agriculture, 1894.*

[2] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 371–483. Also Pfeffer's *Physiology of Plants*, translated by Ewart, Chapter VIII.

the raw materials which are afforded by the earth and air and all the steps of the processes by which these foods are used in the life and growth of the plant are together known as its *nutrition*. When we think more of the chemical side of nutrition than of its relation to plant-life, we call any of the changes or all of them *metabolism*, which means simply chemical transformation in living tissues. There are two main classes of metabolism — the constructive kind, which embraces those changes which build up more complicated substances out of simpler ones (Sect. 179), and the destructive kind, the reverse of the former (Sect. 184). A good many references to cases of plant metabolism have been made in earlier chapters, but the subject comes up in more detail in connection with the study of the work of leaves than anywhere else, because the feeding which the ordinary seed-plant does is very largely done in and by its leaves.

177. Details of the Work of the Leaf. — A leaf has four functions to perform: (1) Starch-making; (2) assimilation;[1] (3) excretion of water; (4) respiration.

178. Absorption of Carbon Dioxide and Removal of its Carbon. — Carbon dioxide is a constant ingredient of the atmosphere, usually occurring in the proportion of about four parts in every 10,000 of air or one twenty-fifth of one per cent. It is a colorless gas, a compound of two simple substances or elements, carbon and oxygen, the former familiar to us in the forms of charcoal and graphite, the latter occurring as the active constituent of air.

[1] In many works on Botany (1) and (2) are both compounded under the term *assimilation*. Many botanists (most of the American ones) apply the name *photosynthesis* or *photosyntax* to the starch-making process, but these names are not wholly satisfactory, and perhaps it is as well (as suggested by Professor Atkinson) to name the process from its result.

Carbon dioxide is produced in immense quantities by the decay of vegetable and animal matter, by the respiration of animals, and by all fires in which wood, coal, gas, or petroleum is burned.

Green leaves and the green parts of plants, when they contain a suitable amount of potassium salts, have the power of removing carbon dioxide from the air (or in the case of some aquatic plants from water in which it is dissolved), retaining its carbon and setting free part or all of the oxygen. This process is an important part of the work done by the plant in making over raw materials into food from which it forms its own substance.

EXPERIMENT XXXIV

Oxygen-Making in Sunlight. — Place a green aquatic plant in a glass jar full of ice-cold fresh water, in front of a sunny window.[1] Place a thermometer in the jar, watch the rise of temperature, and note at what point you first observe the formation of oxygen-bubbles. Remove to a dark closet for a few minutes and examine by lamplight, to see whether the rise of bubbles still continues.

This gas may be shown to be oxygen by collecting some of it in a small inverted test-tube filled with water and thrusting the glowing coal of a match just blown out into the gas. It is not, however, very easy to do this satisfactorily before the class.

Repeat the experiment, using water which has been well boiled and then quickly cooled. Boiling removes all the dissolved gases from water, and they are not re-dissolved in any considerable quantity for many hours.

[1] *Elodea, Myriophyllum, Chrysosplenium, Potamogeton, Fontinalis,* any of the green aquatic flowering plants, or even the common confervaceous plants, known as *pond-scum* or "frog-spit," will do for this experiment.

Ordinary air, containing a known per cent of carbon dioxide, if passed very slowly over the foliage of a plant covered with a bell-glass and placed in full sunlight, will, if tested chemically, on coming out of the bell-glass be found to have lost a little of its carbon dioxide. The pot in which the plant grows must be covered with a lid, closely sealed on, to prevent air charged with carbon dioxide (as the air of the soil is apt to be) from rising into the bell-glass.

179. Disposition made of the Absorbed Carbon Dioxide. — It would lead the student too far into the chemistry of botany to ask him to follow out in detail the changes by which carbon dioxide lets go part at least of its oxygen and gives its remaining portions, namely, the carbon, and perhaps part of its oxygen, to build up the substance of the plant. Starch is composed of three elements: hydrogen (a colorless, inflammable gas, the lightest of known substances), carbon, and oxygen. Water is composed largely of hydrogen, and, therefore, carbon dioxide and water contain all the elements necessary for making starch. The chemist cannot put these elements together to form starch, but the plant can do it, and at suitable temperatures starch-making goes on constantly in the green parts of plants when exposed to sunlight and supplied with water and carbon dioxide.[1] The seat of the manufacture is in the chlorophyll bodies, and protoplasm is without doubt the manufacturer, but the process is not understood by chemists or botanists. No carbon dioxide can be taken up and used by plants growing in the dark, nor in an atmosphere containing only carbon dioxide, even in the light.

[1] Very likely the plant makes sugar first of all and then rapidly changes this into starch. However that may be, the first kind of food made in the leaf and retained long enough to be found there by ordinary tests is starch. See Pfeffer's *Physiology of Plants*, translated by Ewart, Vol. I, pp. 317, 318.

Plate V. — A Saprophyte, Indian Pipe

A very good comparison of the leaf to a mill has been made as follows[1]:

The mill:	Palisade-cells and underlying cells of the leaf.
Raw material used:	Carbon dioxide, water.
Milling apparatus:	Chlorophyll grains.
Energy by which the mill is run:	Sunlight.
Manufactured product:	Starch.
Waste product:	Oxygen.

180. Plants Destitute of Chlorophyll not Starch-Makers. — Aside from the fact that newly formed starch grains are first found in the chlorophyll bodies of the leaf and the green layer of the bark, one of the best evidences of the intimate relation of chlorophyll to starch-making is derived from the fact that plants which contain no chlorophyll cannot make starch from water and carbon dioxide. Parasites, like the dodder, which are nearly destitute of green coloring matter, cannot do this; neither can *saprophytes* or plants which live on decaying or fermenting organic matter, animal or vegetable. Most saprophytes, like the moulds, toadstools, and yeast, are flowerless plants of low organization, but there are a few (such as the Indian pipe (Plate V), which flourishes on rotten wood or among decaying leaves) that bear flowers and seeds.

181. Detection of Starch in Leaves. — Starch may be found in abundance by microscopical examination of the green parts of growing leaves, or its presence may be shown by testing the whole leaf with iodine solution.

[1] By Professor George L. Goodale.

EXPERIMENT XXXV

Occurrence of Starch in Nasturtium Leaves. — Toward the close of a very sunny day collect some bean leaves or leaves of nasturtium (*Tropæolum*). Boil these in water for a few minutes, to kill the protoplasmic contents of the cells and to soften and swell the starch grains.[1]

Soak the leaves, after boiling, in strong alcohol for a day or two, to dissolve out the chlorophyll, which would otherwise make it difficult to see the blue color of the starch test, if any were obtained. Rinse out the alcohol with plenty of water and then place the leaves for ten or fifteen minutes in a solution of iodine, rinse off with water and note what portions of the leaf, if any, show the presence of starch.

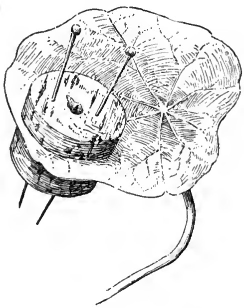


Fig. 123. — Leaf of Tropæolum partly covered with Disks of Cork and exposed to Sunlight.

EXPERIMENT XXXVI

Consumption of Starch in Nasturtium (*Tropæolum*) Leaves. — Select some healthy leaves of Tropæolum on a plant growing vigorously indoors or, still better, in the open air. Shut off the sunlight from parts of the selected leaves (which are to be left on the plant and as little injured as may be) by pinning circular disks of cork on opposite sides of the leaf, as shown in Fig. 123. On the afternoon of the next day remove these leaves from the plant and treat as described in the preceding experiment, taking especial pains to get rid of all the chlorophyll by changing the alcohol as many times as may be necessary. What does this experiment show in regard to the consumption of starch in the leaf? What has caused its disappearance?

182. Rate at which Starch is manufactured. — The amount of starch made in a day by any given area of

[1] The leaves, collected as above described, may, after boiling, be kept in alcohol for winter use. They also make excellent material for the microscopical study of starch in the leaf.

foliage must depend on the kind of leaves, the temperature of the air, the intensity of the sunlight, and some other circumstances. Sunflower leaves and pumpkin or squash leaves have been found to manufacture starch at about the same rate. In a summer day fifteen hours long they can make nearly three-quarters of an ounce of starch for each square yard of leaf-surface. A full-grown squash leaf has an area of about one and one-eighth square feet, and a plant may bear as many as 100 leaves. What would be the daily starch-making capacity of such a plant?[1]

183. Assimilation. — From the starch in the leaf, grape-sugar or malt-sugar is readily formed, and some of this in turn is apparently combined on the spot with nitrogen, sulphur, and phosphorus. These elements are derived from nitrates, sulphates, and phosphates, taken up in a dissolved condition by the roots of the plant and transported to the leaves. The details of the process are not understood, but the result of the combination of the sugars or similar substances with suitable (very minute) proportions of nitrogen, sulphur, and phosphorus is to form complex nitrogen compounds. These are not precisely of the same composition as the living protoplasm of plant-cells or as the reserve proteids stored in seeds (Sects. 14, 17), stems (Sect. 127), and other parts of plants, but are readily changed into protoplasm or proteid foods as necessity may demand.

Assimilation is by no means confined to leaves ; indeed, most of it, as above suggested, must take place in other parts of the plant. For instance, the manufacture of the immense amounts of cellulose, of cork, and of the com-

[1] See Pfeffer's *Physiology of Plants*, translated by Ewart, Vol. I, p. 324.

pound (*lignin*) characteristic of wood-fiber, that go to make up the main bulk of a large tree must be carried on in the roots, trunk, and branches of the tree.

184. Digestive Metabolism. — Plant-food in order to be carried to the parts where it is needed must be dissolved, and this dissolving often involves a chemical change and is somewhat similar to digestion as it occurs in animals. The newly made starch in the leaf must be changed to a sugar or other substance soluble in water before it can be carried to the parts of the plant where it is to be stored or to rapidly growing parts where it is to be used for building material. On the other hand, starch, oil, and such insoluble proteids as are deposited in the outer portion of the kernel of wheat and other grains are extremely well adapted to serve as stored food, but on account of their insoluble nature are quite unfit to circulate through the tissues of the plant. The various kinds of sugar are not well adapted for storage, since they ferment easily in the presence of warmth and moisture if yeast-cells or suitable kinds of bacteria are present.

Two important differences between starch-making in the green parts of plants and the non-constructive or the destructive type of metabolism should be carefully noticed. These latter kinds of metabolism go on in the dark as well as in the light and do not add to the total weight of the plant.

185. Excretion of Water and Respiration. — Enough has been said in Sect. 174 concerning the former of these processes. *Respiration*, or breathing in oxygen and giving off carbonic acid gas, is an operation which goes on constantly in plants, as it does in animals, and is necessary to their life. For, like animals, plants get the energy with which they do the work of assimilation, growth, reproduction, and performing their movements from the oxidation of such combustible substances as oil, starch, and sugar.[1]

The amount of oxygen absorbed and of carbonic acid given off is, however, so trifling compared with the amount of each gas passing in the opposite direction, while starch-making is going on in sunlight, that under such circumstances it is difficult to observe the occurrence of respiration. In ordinary leafy plants the leaves (through their stomata) are the principal organs for absorption of air, but much air passes into the plant through the lenticels of the bark.

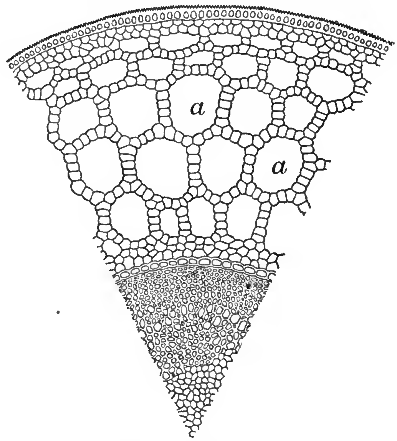


FIG. 124. — Cross-Section of Stem of Marestail (*Hippuris*) with Air-Passages, *a*.

In partly submerged aquatics especial provisions are found for carrying the air absorbed by the leaves down to the submerged parts. This is accomplished in pond lilies by ventilating tubes which traverse the leaf-stalks lengthwise. In many cases such channels run up and down the stem (Fig. 124).

[1] The necessity of an air supply about the roots of the plant may be shown by filling the pot or jar in which the hydrangea was grown for the transpiration experiment perfectly full of water and noting the subsequent appearance of the plant at periods twelve to twenty-four hours apart.

186. Tabular Summary of Metabolic and Other Processes.[1]

Name of process	By what apparatus or agency carried on	By what kind of energy carried on	Substances acted on	Useful products	Waste products
Starch-making	Chlorophyll bodies of leaves and green stems	Sunlight and heat, energy of protoplasm	Carbon dioxide and water	Sugar and starch	Oxygen, passed out of stomata
Assimilation (Tissue Building)	Living protoplasm in leaves and elsewhere		Sugar and compounds containing nitrogen, sulphur, and phosphorus	Proteids for storage. Protoplasm for live, active cells	
Digestion	Various ferments or enzymes		Starch, cellulose, stored proteids	Sugars, proteids in soluble forms	
Excretion of water (Transpiration)	Cells of pulpy interior of leaf around air spaces	Heat, vaporizing water	Soil-water brought up from roots	Potassium salts and other useful inorganic compounds stored	Water vapor, passed out of stomata. Lime salts, silica, etc., deposited in the leaf
Respiration (Breathing)	All live cells of interior of root, stem or leaf when supplied with air	Chemical attraction between oxygen and combustible substances	Sugars and oils	Energy (*i.e.*, power to do work)	Carbonic acid gas, water

[1] It is to be understood that this table only includes a small portion of the whole series of metabolic processes which go on in green plants, but it embraces some of the most important ones. Excretion of water is not a metabolic process, but is inserted here for the purpose of making the showing of the work of the leaf as complete as possible.

187. The Fall of the Leaf. — In the tropics trees retain most of their leaves the year round; a leaf occasionally falls, but no considerable portion of them drops at any one season.[1] The same statement holds true in regard to our cone-bearing evergreen trees, such as pines, spruces, and the like. But the impossibility of absorbing soil-water when the ground is at or near the freezing temperature (Exp. XVII) would cause the death, by drying up, of trees with broad leaf-surfaces in a northern winter. And in countries where there is much snowfall, most broad-leafed trees could not escape injury to their branches from overloading with snow, except by encountering winter storms in as close-reefed a condition as possible. For such reasons our common shrubs and forest trees (except the cone-bearing, narrow-leafed ones already mentioned) are mostly *deciduous*, that is they shed their leaves at the approach of winter.

The fall of the leaf is preceded by important changes in the contents of its cells.

EXPERIMENT XXXVII

Does the Leaf vary in its Starch Contents at Different Seasons?

Collect in early summer some leaves of several kinds of trees and shrubs and preserve them in alcohol. Collect others as they are beginning to drop from the trees in autumn and preserve them in the same way. Test some of each lot for starch as described in Sect. 181.

What does the result indicate?

Much of the sugary and protoplasmic contents of the leaf disappears before it falls. These valuable materials

[1] Except where there is a severe dry season.

have been absorbed by the branches and roots, to be used again the following spring.

The separation of the leaf from the twig is accomplished by the formation of a layer of cork cells across the base of the petiole in such a way that the latter finally breaks off across the surface of the layer. A waterproof scar is thus already formed before the removal of the leaf, and there is no waste of sap dripping from the wound where the leaf-stalk has been removed, and no chance for moulds to attack the bark or wood and cause it to decay. In compound leaves each leaflet may become separated from the petiole, as is notably the case with the horse-chestnut leaf (Fig. 102). In woody monocotyledons, such as palms, the leaf-stalks do not commonly break squarely off at the base, but wither and leave projecting stumps on the stem (Plate VI).

The brilliant coloration, yellow, scarlet, deep red, and purple, of autumn leaves is popularly but wrongly supposed to be due to the action of frost. It depends merely on the changes in the chlorophyll grains and the liquid cell-contents that accompany the withdrawal of the proteid material from the tissues of the leaf. The chlorophyll turns into a yellow insoluble substance after the valuable materials which accompany it have been taken away, and the cell sap at the same time may turn red. Frost perhaps hastens the break-up of the chlorophyll, but individual trees often show bright colors long before the first frost, and in very warm autumns most of the changes in the foliage may come about before there has been any frost.

188. Tabular Review of Experiments.

[Continue the table from Sect. 128.]

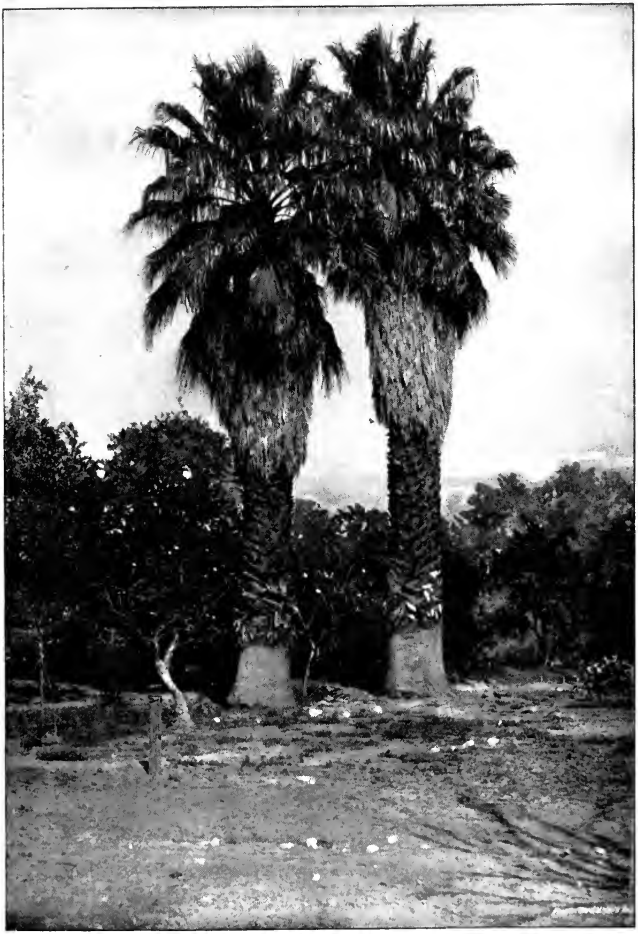


PLATE VI. — Fan Palms

189. Review Summary of Minute Structure of Leaves.[1]

General structure, distribution of parenchyma, and prosenchyma
Layers of tissue seen on a cross-section . . . .
Structure of epidermis . . .
Structure of stomata . . . .
Distribution of stomata . . .
Structure and distribution of chlorophyll bodies . . . .

190. Review Summary of Functions of Leaves.

Principal uses of . . . .
- fibro-vascular bundles
- epidermis . . . .
- stomata . . . .
- air spaces . . . .
- palisade-cells . . .
- spongy parenchyma
- waxy coating . . .
- hairs . . . . .

Substances received by the leaf . . . .
- from the air . . .
- from the soil . . .

Substances manufactured by the leaf . .

Substances given off by the leaf . . .
- into the air . . .
- into the stem . .

Mineral substances accumulated in the leaf
Statistics in regard to transpiration . .
Statistics in regard to starch-making . .

[1] Illustrate with sketches and diagrams.

CHAPTER XII

PROTOPLASM AND ITS PROPERTIES

191. The Cell in its Simplest Form. — Sufficient has been said in the preceding chapters, and enough tissues have been microscopically studied, to make it pretty clear what vegetable cells, as they occur in flowering plants, are like. In Chapter XI, leaf-cells have been taken for granted and their work described in some detail. Before going further, it is worth while to consider the structure of an individual cell, and to see of what kinds of activity it is capable.

In studying the minute anatomy of bark, wood, pith, and other tissues the attention is often directed to the *cell-wall* without much regard to the nature of the *cell-contents*. Yet the cell-wall is not the cell, any more than the lobster shell or the crayfish shell is the lobster or the crayfish. *The contained protoplasm with its nucleus is the cell.*[1] The cell reduced to its lowest terms need not have a cell-wall, but may consist simply of a mass of protoplasm, usually containing a portion of denser consistency than the main bulk, known as the *nucleus*.

Such cells, without a cell-wall, are not common in the vegetable world, but are frequently encountered among animals.

192. The Slime Moulds.[2] — One of the best examples of masses of naked protoplasm leading an individual existence

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, pp. 21–51.

[2] Strasburger, Noll, Schenk, and Schimper's *Text-Book of Botany*, pp. 50–52 and 302–305.

is found in the slime moulds, which live upon rotten tan bark, decaying wood, and so on. These curious organisms have so many of the characteristics both of animals and of plants that they have been described in zoölogies under the former title and in botanies under the latter one. Perhaps it would not really be so absurd a statement as it might seem, to say that every slime mould leads the life of an animal during one period of its existence and of a plant at another period. At any rate, whatever their true nature, these little masses of unenclosed protoplasm illustrate admirably some of the most important properties of protoplasm. Slime moulds spring from minute bodies called *spores* (Fig. 125, *a*) which differ from the seeds of seed-plants not only in their microscopic size but still more in their lack of an embryo. The spores of slime moulds are capable, when kept dry, of preserving for many years their power of germination, but in the presence of moisture and warmth they will germinate as soon as they are scattered. During the process of germination the spore swells, as shown at *b*, and then bursts, discharging its protoplasmic contents, as seen at *c* and *d*. This in a few minutes lengthens out and produces at one end a hair-like *cilium*, as shown at *e*, *f*, *g*. These ciliated bodies are called *swarmspores*, from their power of swimming freely about by the vibrating motion of the cilia. Every swarm-spore has at its ciliated end a *nucleus*, and at the other end a bubble-like object which gradually expands, quickly disappears, and then again expands. This *contractile vacuole* is commonly met with in animalcules, and increases the likeness between the slime moulds and many microscopic animals. The next change of the swarmspores is into an

Amœba form (so called from one of the most interesting and simplest of animals, the *Amœba*, found on the surface of

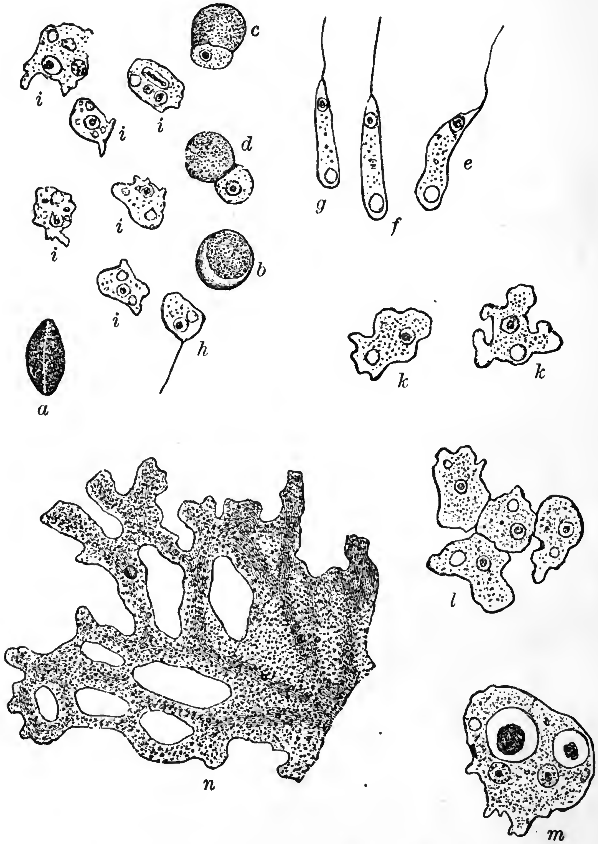


FIG. 125. — A Slime Mould. (*a–m*, inclusive, × 540 times, *n* × 90 times.)

mud and the leaves of water plants). In this condition, as shown at *h*, *i*, *k*, the spores creep about over the surface of the decaying vegetable material on which the slime moulds live. Their movement is caused by a thrusting out of the semi-liquid protoplasm on one side of the mass, and a withdrawal of its substance from the other side. At length many amœba-shaped bodies unite, as at *l*, to form a larger mass, *m*, which finally increases to the protoplasmic network shown at *n*. This eventually collects into a roundish or egg-shaped firm body, inside of which a new crop of spores is produced. It is not easy to trace the manner in which the nourishment of these simple plants is taken. Probably they absorb it from the decaying matter upon which they live during their amœba-like period, and after they have formed the larger masses, *n*.

193. Characteristics of Living Protoplasm.[1] — The behavior of the slime moulds during their growth and transformations, as just outlined, affords a fair idea of several of the remarkable powers which belong to living protoplasm, which have been summed up as follows:

(1) The power to take up new material into its own substance (*selective absorption*). This is not merely a process of soaking up liquids, such as occurs when dry earth or a sponge is moistened. The protoplasmic lining of a root-hair, for example, selects from the soil-water some substances and rejects others (Sect. 65).

(2) The ability to change certain substances into others of different chemical composition (*metabolism*, Sect. 176). Carbon dioxide and water, losing some oxygen in the process, are combined into starch; starch is changed into various kinds of sugar and these back into starch again; starch becomes converted into vegetable acids, into cellulose, or into oil; or the elements of starch are combined

[1] See Huxley's *Essays*, Vol. I, essay on "The Physical Basis of Life."

with nitrogen to make various proteid compounds, either for immediate use or for reserve food. Many other complicated transformations occur.

(3) The power to cast off waste or used-up material (*excretion*). Getting rid of surplus water (Sect. 174) and of oxygen (Sect. 178) constitutes a very large part of the excretory work of plants.

(4) The capacity for growth and the production of offspring (*reproduction*). These are especially characteristic of living protoplasm. It is true that non-living objects may grow in a certain sense, as an icicle or a crystal of salt or of alum in a solution of its own material does. But growth by the process of taking suitable particles into the interior of the growing substance and arranging them into an orderly structure (Fig. 126) is possible only in the case of live protoplasm.

(5) The possession of the power of originating movements not wholly and directly caused by any external impulse (*automatic movements*). Such, for instance, are the lashing movements of the cilia of the swarmspores of slime moulds, or the slow pendulum movements of *Oscillatoria* (Sect. 269), or the slow vibrating movements of the stipules of the "telegraph plant" (*Desmodium*), not uncommon in greenhouses.

(6) The power of shrinking or closing up (*contractility*). This is illustrated by the action of the contractile vacuole of the slime moulds and of many animalcules and by all the muscular movements of animals.

(7) Sensitiveness when touched or otherwise disturbed, for instance, by a change of light or of temperature (*irritability*).

194. Nature and Occurrence of Irritability in Plants.[1] — Mention has already been made of the fact that certain parts of plants respond to suitable *stimuli* that is exciting

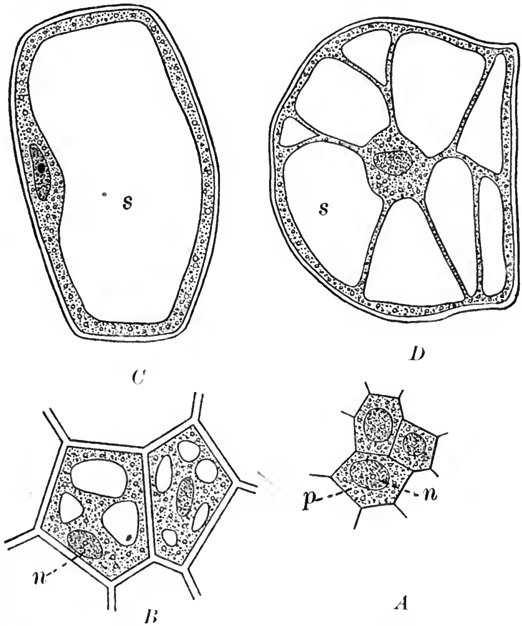


FIG. 126. — Protoplasm in Ovule and Fruit of Snowberry (*Symphoricarpus racemosus*).

A, cells from ovule, × 340; *B*, cells from an ovule further developed, × 340; *C*, *D*, cells from pulp of fruit, × 110; *n*, nucleus; *p*, protoplasm; *s*, cell-sap.

In the young and rapidly growing cells, *A* and *B*, the cell-sap is not present, or present only in small quantities, while in the older cells, *C* and *D*, it occupies a large portion of the interior of the cell.

causes. Geotropic movements (Sect. 70) are due to the response of roots or shoots to gravitation. These

[1] See Strasburger, Noll, Schenk, and Schimper's *Text-Book of Botany*, pp. 160–162 and 269–274.

movements are due to unequal growth induced in the younger portions of the plant by the action of gravitation upon it. Other movements (of ordinary foliage leaves, of the floral leaves of many flowers, and of other parts of a few flowers) are produced by changes in the distention or *turgescence* of some of the cells in the organs which move and have nothing to do with growth. The closing of the leaves of insect-catching plants is briefly described in Sect. 410, and the "sleep" of leaves, due to movements of the pulvini, was described in Sect. 152. A few facts in regard to the opening and closing of flowers will be found in Sect. 440.

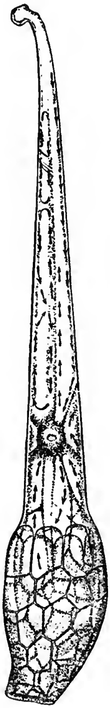


FIG. 127. — Stinging Hair of Nettle, with Nucleus. (Much magnified.) The arrows show the direction of the currents in the protoplasm.

The stimuli which cause movements of leaves or of the irritable parts of flowers are of several kinds. Light is the main cause which induces leaves to open from their night position to that usual in the daytime. In the case of flowers, it is sometimes light and sometimes warmth which causes them to open. Leaves which catch insects may be made to close by touching them, but the sensitive-plants, of which there are several kinds found in the United States, and a much more sensitive one in tropical America, all fold their leaflets, on being touched, into the same position which they assume at night.

195. Circulation of Protoplasm. — When confined by a cell-wall, protoplasm often manifests a beautiful and constant rotating movement, traveling incessantly up one side of the cell and down the other.[1] A more complicated motion is the *circulation of protoplasm*, shown in cells of the jointed blue hairs in the flower of the common spiderwort and in the stinging hairs of the nettle (Fig. 127). The thin cell-wall of each hair is lined with a protoplasmic layer in which are seen many irregular, thread-like currents, marked by the movements of the granules, of which the protoplasmic layer is full.

[1] See Huxley and Martin's *Elementary Biology*, under *Chara*.

CHAPTER XIII

INFLORESCENCE, OR ARRANGEMENT OF FLOWERS ON THE STEM

196. Regular Positions for Flower-Buds. — Flower-buds, like leaf-buds, occur regularly either in the axils of leaves or at the end of the stem or branch and are therefore either axillary or terminal.

197. Axillary and Solitary Flowers; Indeterminate Inflorescence. — The simplest possible arrangement for flowers which arise from the axils of leaves is to have a single flower spring from each leaf-axil. Fig. 128 shows how this plan appears in a plant with opposite leaves. As long as the stem continues to grow, the production of new leaves may be followed by that of new

FIG. 128. — Axillary and Solitary Flowers of Pimpernel.

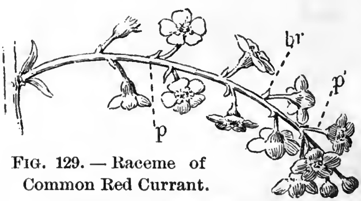


FIG. 129. — Raceme of Common Red Currant. *p*, peduncle; *p'*, pedicel; *br*, bract.

flowers. Since there is no definite limit to the number of flowers which may appear in this way, the mode of flowering just described (with many others of the same general character) is known as *indeterminate inflorescence.*

198. The Racemes and Related Forms. — If the leaves along the stem were to become very much dwarfed and the flowers brought closer together, as they frequently are, a kind of flower-cluster like that of the currant (Fig. 129) or the lily-of-the-valley would result. Such an inflorescence is called a *raceme;* the main flower-stalk is known as the *peduncle;* the little individual flower-stalks are *pedicels*, and the small, more or less scale-like leaves of the peduncle are *bracts*.[1]

FIG. 130. — Simple Umbel of Cherry.

Frequently the lower pedicels of a cluster on the general plan of the raceme are longer than the upper ones and make a somewhat flat-topped cluster, like that of the hawthorn, the sheep laurel, or the trumpet creeper. This is called a *corymb*.

In many cases, for example the parsnip, the Sweet Cicely, the ginseng, and the cherry, a group of pedicels of nearly equal length

FIG. 131. — Catkins of Willow.
A, staminate flowers; *B*, pistillate flowers

[1] It is hardly necessary to say that the teacher will find it better in every way, if material is abundant, to begin the study of flower-clusters with the examination of typical specimens by the class.

spring from about the same point. This produces a flower-cluster called the *umbel* (Fig. 130).

199. Sessile Flowers and Flower-Clusters. — Often the pedicels are wanting, or the flowers are sessile, and then a modification of the raceme is produced which is called a *spike*, like that of the plantain (Fig. 132). The willow, alder, birch, poplar, and many other common trees bear a short, flexible, rather scaly spike (Fig. 131), which is called a *catkin*.

The peduncle of a spike is often so much shortened as to bring the flowers into a somewhat globular mass. This is called a *head* (Fig. 132). Around the base of the head usually occurs a circle of bracts known as the *involucre*. The same name is given to a set of bracts which often surround the bases of the pedicels in an umbel.

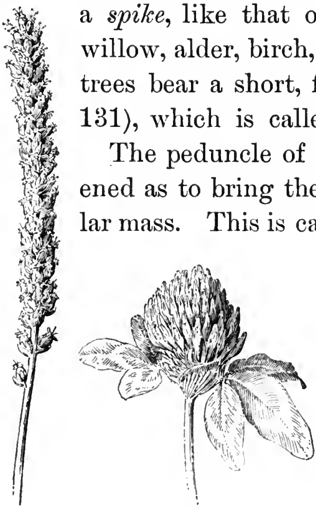


Fig. 132. — Spike of Plantain and Head of Red Clover.

200. The Composite Head. — The plants of one large group, of which the dandelion, the daisy, the thistle, and the sunflower are well-known members, bear their flowers in close involucrate heads on a common receptacle. The whole cluster looks so much like a single flower that it is usually taken for one by non-botanical people. In many of the largest and most showy heads, like that of the sunflower and the daisy, there are two kinds of flowers, the *ray-flowers*, around the margin, and the tubular *disk-flowers* of the interior of the head (Fig. 133). The early botanists supposed the whole flower-cluster to be a single

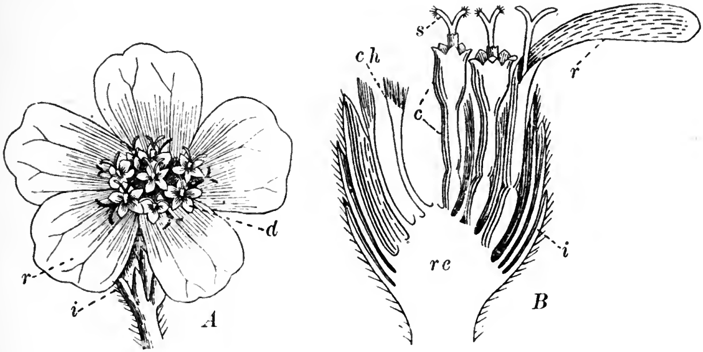


FIG. 133.—Head of Yarrow.

A, top view. (Magnified.) *B*, lengthwise section. (Magnified.) *re*, receptacle; *i*, involucre; *r*, ray-flowers; *d*, disk-flowers; *c*, corolla; *s*, stigma; *ch*, chaff, or bracts of receptacle.

FIG. 134.
Panicle of Oat.

FIG. 135.—Compound Umbel of Carrot.

compound flower. This belief gave rise to the name of one family of plants, *Compositæ*, that is, plants with compound flowers. In such heads as those of the thistle, the cud weed, and the everlasting there are no ray-flowers, and in others, like those of the dandelion and the chicory, all the flowers are ray-flowers.

201. Compound Flower-Clusters. — If the pedicels of a raceme branch, they may produce a compound raceme, or

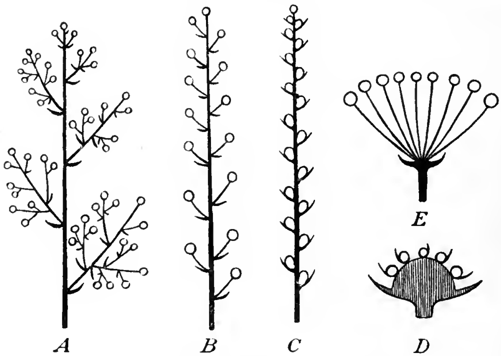


FIG. 136. — Diagrams of Inflorescence.
A, panicle; *B*, raceme; *C*, spike; *E*, umbel; *D*, head.

panicle, like that of the oat (Fig. 134).[1] Other forms of compound racemes have received other names.

An umbel may become compound by the branching of its flower-stalks (Fig. 135), each of which then bears a little umbel, an *umbellet*.

202. Inflorescence Diagrams. — The plan of inflorescence may readily be indicated by diagrams like those of Fig. 136.

The student should construct such diagrams for some rather complicated flower-clusters, like those of the grape, horse-chestnut or buckeye, hardhack, vervain, or many grasses.

[1] Panicles may also be formed by compound cymes (see Sect. 204).

203. Terminal Flowers; Determinate Inflorescence. — The terminal bud of a stem may be a flower-bud. In this case the direct growth of the stem is stopped or determined by the appearance of the flower; hence such plants are said to have a *determinate inflorescence.* The simplest possible case of this kind is that in which the stem bears but one flower at its summit.

204. The Cyme. — Very often flowers appear from lateral (axillary) buds, below the terminal flower, and thus give rise to a flower-cluster called a *cyme.* This may have only three flowers, and in that case would look very much like a three-flowered umbel. But in the raceme, corymb, and umbel the order of flowering is from below upward, or from the outside of the cluster inward, because the lowest or the outermost flowers are the oldest, while in determinate forms of inflorescence the central flower is the oldest, and therefore the order of blossoming is from the center outwards. Cymes are very commonly compound, like those of the elder and of many plants of the pink family, such as the Sweet William and the mouse-ear chickweed (Fig. 137). They may also, as already mentioned, be panicled, thus making a cluster much like Fig. 136, *A*.

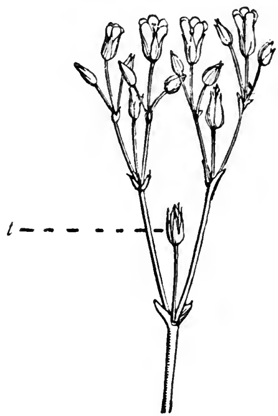


FIG. 137. — Compound Cyme of Mouse-Ear Chickweed.
t, the terminal (oldest) flower.

CHAPTER XIV

THE STUDY OF TYPICAL FLOWERS

(Only one of the three flowers described to be studied by aid of these directions.)

205. The Flower of the Trillium. — Cut off the flower-stalk rather close to the flower; stand the latter, face down, on the table, and draw the parts then shown. Label the green leaf-like parts *sepals*, and the white parts, which alternate with these, *petals*. Turn the flower face up, and make another sketch, labeling the parts as before, together with the yellow enlarged extremities or *anthers* of the stalked organs called *stamens*.

Note and describe the way in which the petals alternate with the sepals. Observe the arrangement of the edges of the petals toward the base, — how many with both edges outside the others, how many with both edges inside, how many with one edge in and one out.

Note the veining of both sepals and petals, more distinct in which set?[1]

Pull off a sepal and make a sketch of it, natural size; then remove a petal, flatten it out, and sketch it, natural size.

Observe that the flower-stalk is enlarged slightly at the upper end into a rounded portion, the *receptacle*, on which all the parts of the flower rest.

Note how the six stamens arise from the receptacle and their relations to the origins of the petals. Remove the remaining petals

[1] In flowers with delicate white petals the distribution of the fibro-vascular bundles in these can usually be readily shown by standing the freshly cut end of the peduncle in red ink for a short time, until colored veins begin to appear in the petals. The experiment succeeds readily with apple, cherry, or plum blossoms; with white gilliflower the coloration is very prompt. Lily-of-the-valley is perhaps as interesting a flower as any on which to try the experiment, since the well-defined stained stripes are separated by portions quite free from stain, and the pistils are also colored.

(cutting them off near the bottom with a knife), and sketch the stamens, together with the other object, the *pistil*, which stands in the center.

Cut off one stamen, and sketch it as seen through the magnifying glass. Notice that it consists of a greenish stalk, the *filament*, and a broader portion, the *anther* (Fig. 149). The latter is easily seen to contain a prolongation of the green filament, nearly surrounded by a yellow substance. In the bud it will be found that the anther consists of two long pouches or *anther-cells*, which are attached by their whole length to the filament, and face inward (towards the center of the flower). When the flower is fairly open, the anther-cells have already split down their margins, and are discharging a yellow, somewhat sticky powder, the *pollen*.

Examine one of the anthers with the microscope, using the two-inch objective, and sketch it.

Cut away all the stamens, and sketch the *pistil*. It consists of a stout lower portion, the *ovary*, which is six-ridged or angled, and which bears at its summit three slender *stigmas*.

In another flower, which has begun to wither (and in which the ovary is larger than in a newly opened flower), cut the ovary across about the middle, and try to make out with the magnifying glass the number of chambers or *cells* which it contains. Examine the cross-section with the two-inch objective; sketch it, and note particularly the appearance and mode of attachment of the undeveloped seeds or *ovules* with which it is filled. Make a vertical section of another rather mature ovary, and examine this in the same way.

Using a fresh flower, construct a diagram to show the relation of the parts on an imaginary cross-section, as illustrated in Fig. 157.[1] Construct a diagram of a longitudinal section of the flower, on the general plan of those in Fig. 155, but showing the contents of the ovary.

Make a tabular list of the parts of the flower, beginning with the sepals, giving the order of parts and number in each set.

[1] It is important to notice that such a diagram is not a picture of the section actually produced by cutting through the flower crosswise at any one level, but that it is rather a *projection* of the sections through the most typical part of each of the floral organs.

206. The Flower of the Tulip.[1] — Make a diagram of a side view of the well-opened flower, as it appears when standing in sunlight. Observe that there is a set of outer flower-leaves and a set of inner ones.[2] Label the outer set *sepals* and the inner set *petals*. In most flowers the parts of the outer set are greenish, and those of the inner set of some other color. It is often convenient to use the name *perianth*, meaning around the flower, for the two sets taken together. Note the white waxy bloom on the outer surface of the outer segments of the perianth. What is the use of this? Note the manner in which the inner segments of the perianth arise from the top of the peduncle and their relation to the points of attachment of the outer segments. In a flower not too widely opened, note the relative position of the inner segments of the perianth, how many wholly outside the other two, how many wholly inside, how many with one edge in and one edge out.

Remove one of the sepals by cutting it off close to its attachment to the peduncle, and examine the veining by holding it up in a strong light and looking through it. Make a sketch to show the general outline and the shape of the tip.

Examine a petal in the same way, and sketch it.

Cut off the remaining portions of the perianth, leaving about a quarter of an inch at the base of each segment. Sketch the upright, triangular, pillar-like object in the center, label it *pistil*, sketch the organs which spring from around its base, and label these *stamens*.

Note the fact that each stamen arises from a point just above and within the base of a segment of the perianth. Each stamen consists of a somewhat conical or awl-shaped portion below, the *filament*, surmounted by an ovate linear portion, the *anther*. Sketch one of the stamens about twice natural size and label it × 2. Is the attachment of the anther to the filament such as to admit of any nodding or twisting movement of the former? In a young flower, note the two tubular pouches or anther-cells of which the anther is composed, and the slits by which these open. Observe the dark-colored *pollen*

[1] *Tulipa Gesneriana*. As the flowers are rather expensive, and their parts are large and firm, it is not absolutely necessary to give a flower to each pupil, but some may be kept entire for sketching and others dissected by the class. All the flowers must be single.

[2] Best seen in a flower which is just opening.

which escapes from the anther-cells and adheres to paper or to the fingers. Examine a newly opened anther with the microscope, using the two-inch objective, and sketch it.

Cut away all the stamens and note the two portions of the pistil, a triangular prism, the *ovary*, and three roughened scroll-like objects at the top, the three lobes of the *stigma*. Make a sketch of these parts about twice natural size, and label them × 2. Touch a small camel's-hair pencil to one of the anthers, and then transfer the pollen thus removed to the stigma. This operation is merely an imitation of the work done by insects which visit the flowers out of doors. Does the pollen cling readily to the rough stigmatic surface? Examine this adhering pollen with the two-inch objective, and sketch a few grains of it, together with the bit of the stigma to which it clings. Compare this drawing with Fig. 162. Make a cross-section of the ovary about midway of its length, and sketch the section as seen through the magnifying glass. Label the three chambers shown *cells of the ovary* [1] or *locules*, and the white egg-shaped objects within *ovules*.[2]

Make a longitudinal section of another ovary, taking pains to secure a good view of the ovules, and sketch as seen through the magnifying glass.

Making use of the information already gained and the cross-section of the ovary as sketched, construct a diagram of a cross-section of the entire flower on the same general plan as those shown in Fig. 157.[3]

Split a flower lengthwise,[4] and construct a longitudinal section of the entire flower on the plan of those shown in Fig. 155, but showing the contents of the ovary.

207. The Flower of the Buttercup. — Make a diagram of the mature flower as seen in a side view, looking a little down into it. Label the pale greenish-yellow, hairy, outermost parts *sepals*, and

[1] Notice that the word *cell* here means a comparatively large cavity, and is not used in the same sense in which we speak of a wood-cell or a pith-cell.

[2] The section will be more satisfactory if made from an older flower, grown out of doors, from which the perianth has fallen. In this case label the contained objects *seeds*.

[3] Consult also the footnote on p. 193.

[4] One will do for an entire division of the class.

the larger bright yellow parts above and within these *petals*, and the yellow-knobbed parts which occupy a good deal of the interior of the flower *stamens*.

Note the difference in the position of the sepals of a newly opened flower and that of the sepals of a flower which has opened as widely as possible. Note the way in which the petals are arranged in relation to the sepals. In an opening flower observe the arrangement of the edges of the petals, how many entirely outside the others, how many entirely inside, how many with one edge in and the other out.

Cut off a sepal and a petal, each close to its attachment to the flower; place both, face down, on a sheet of paper, and sketch about twice the natural size and label it × 2. Describe the difference in appearance between the outer and the inner surface of the sepal and of the petal. Note the little scale at the base of the petal, inside.

Strip off all the parts from a flower which has lost its petals, until nothing is left but a slender conical object a little more than an eighth of an inch in length. This is the *receptacle* or summit of the peduncle.

In a fully opened flower, note the numerous yellow-tipped *stamens*, each consisting of a short stalk, the *filament*, and an enlarged yellow knob at the end, the *anther*. Note the division of the anther into two portions, which appear from the outside as parallel ridges, but which are really closed tubes, the *anther-cells*.

Observe in the interior of the flower the somewhat globular mass (in a young flower almost covered by the stamens). This is a group of *pistils*. Study one of these groups in a flower from which the stamens have mostly fallen off, and make an enlarged sketch of the head of pistils. Remove some of the pistils from a mature head, and sketch a single one as seen with the magnifying glass. Label the little knob or beak at the upper end of the pistil *stigma*, and the main body of the pistil the *ovary*. Make a section of one of the pistils, parallel to the flattened surfaces, like that shown in Fig. 150, and note the partially matured seed within.

CHAPTER XV

PLAN AND STRUCTURE OF THE FLOWER AND ITS ORGANS

208. Parts or Organs of the Flower. — Most showy flowers consist, like those studied in the preceding chapter, of four circles or sets of organs, the sepals, petals, stamens, and pistils. The sepals, taken together, constitute the *calyx;* the petals, taken together, constitute the *corolla* (Fig. 138).[1] Sometimes it is convenient to have a word to comprise both calyx and corolla; for this the term *perianth* is used. A flower which contains all four of these sets is said to be *complete.* Since the work of the flower is to produce seed, and seed-forming is due to the coöperation of stamens and pistils, or, as they are often called from their relation to the reproductive organs of spore-plants, *microsporophylls* and *macrosporophylls* (see Sect. 374), these are known as the *essential organs* (Fig. 138). The simplest possible pistil is a dwarfed and

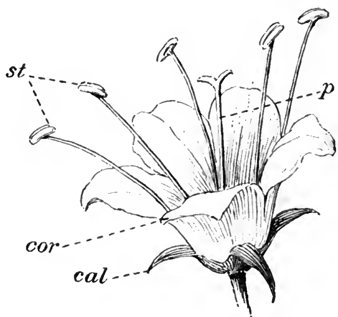


FIG. 138. — The Parts of the Flower. *cal*, calyx; *cor*, corolla; *st*, stamens; *p*, pistil.

[1] The flower of the waterleaf *Hydrophyllum canadense*, modified by the omission of the hairs on the stamens, is here given because it shows so plainly the relation of the parts.

greatly modified leaf (Sect. 222), adapted into a seed-bearing organ. Such a pistil may be one-seeded, as in Fig. 166, or several-seeded, as in the diagrammatic one (Fig. 150); it is called a *carpel*. The calyx and corolla are also known as the *floral envelopes*. Flowers which have the essential organs are called *perfect flowers*. They may, therefore, be perfect without being complete. Incomplete flowers with only one row of parts in the perianth are said to be *apetalous* (Fig. 139).

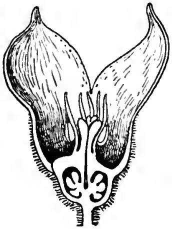


FIG. 139. — Apetalous Flower of (European) Wild Ginger.

209. Regular and Symmetrical Flowers. — A flower is *regular* if all the parts of the same set or circle are alike in size and shape, as in the stonecrop (Fig. 140). Such flowers as that of the violet, the monkshood, and the sweet pea (Fig. 141) are irregular. *Symmetrical* flowers are those whose calyx, corolla, circle of stamens, and set of carpels consist each of the same number of parts, or in which the number in every case is a multiple of the smallest number found in any set. The stonecrop is

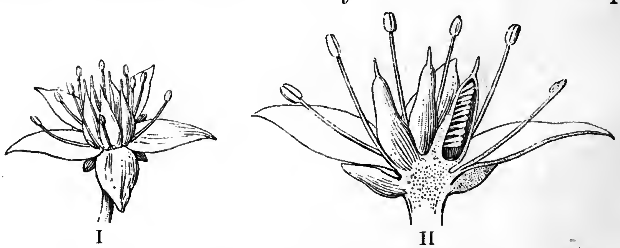


FIG. 140. — Flower of Stonecrop.
I, entire flower (magnified); II, vertical section (magnified).

symmetrical, since it has five sepals, five petals, ten stamens, and five carpels. Roses, mallows, and mignonette are familiar examples of flowers which are unsymmetrical because they have a large, indefinite number of stamens; the portulaca is unsymmetrical, since it has two divisions of the calyx, five or six petals, and seven to twenty stamens.

210. The Receptacle. — The parts of the flower are borne on an expansion of the peduncle, called the *receptacle.* Usually, as in the flower of the grape (Fig. 250), this is only a slight enlargement of the peduncle, but in

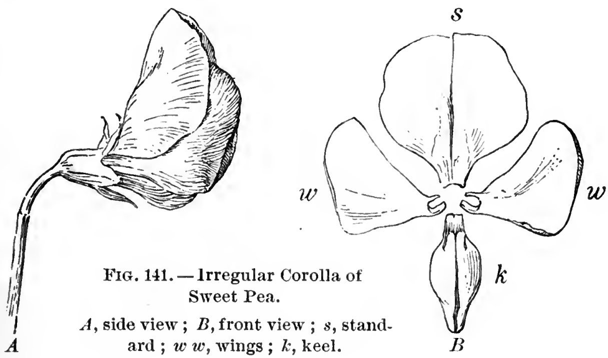


FIG. 141. — Irregular Corolla of Sweet Pea.

A, side view; *B*, front view; *s*, standard; *w w*, wings; *k*, keel.

the lotus and the magnolia the receptacle is of great size, particularly after the petals have fallen and the seed has ripened. The receptacle of the rose (Fig. 142) is hollow, and the pistils arise from its interior surface.

211. Imperfect or Separated Flowers. — The stamens and pistils may be produced in separate flowers, which are, of course, *imperfect.* This term does not imply that such flowers do their work any less perfectly than others, but only that they have not both kinds of essential organs. In the very simple imperfect flowers of the willow (Fig. 143) each flower of the catkin (Fig. 131) consists merely of a pistil or a group of (usually two) stamens, springing from the axil of a small bract.

Staminate and pistillate flowers may be borne on different plants, as they are in the willow, or they may be borne on the same plant, as in the hickory and the hazel, among trees, or in the castor-oil plant, Indian corn, and the begonias. When staminate and pistillate flowers are borne on separate plants, such a plant is said to be *diœcious*, that is, of two households; when both kinds of flower appear on the same individual, the plant is said to be *monœcious*, that is, of one household.

212. Study of Imperfect Flowers. — Examine, draw, and describe the imperfect flowers of some of the following diœcious plants and one of the monœcious plants:[1]

Diœcious plants	early meadow rue. willow. poplar.
Monœcious plants	walnut, oak, chestnut. hickory, alder, beech. birch, hazel, begonia.

213. Union of Similar Parts of the Perianth. — The sepals may appear to join or *cohere* to form a calyx which is more or less entirely united into one piece, as in Figs. 139 and 148. In this case the calyx is said to be *gamosepalous*, that is, of wedded sepals. In the same way the corolla is frequently *gamopetalous*, as in Figs. 144–148. Frequently the border or *limb* of the calyx or corolla is more or less cut or lobed. In this case the projecting

[1] For figures or descriptions of these or allied flowers consult Gray's *Manual of Botany*, Emerson's *Trees and Shrubs of Massachusetts*, Newhall's *Trees of the Northern United States*, or Le Maout and Decaisne's *Traité Général de Botanique*.

portions of the limb are known as divisions, teeth, or lobes.[1] Special names of great use in accurately describing plants are given to a large number of forms of the gamopetalous corolla. Only a few of these names are here given, in connection with the figures.

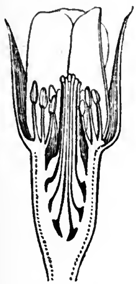


FIG. 142. A Rose, Longitudinal Section.

When the parts of either circle of the perianth are wholly unconnected with each other, that is, polysepalous or polypetalous, such parts are said to be *distinct*.

214. Parts of the Stamen and the Pistil. — The stamen usually consists of a hollow portion, the *anther* (Fig. 149, *a*), borne on a stalk called the *filament* (Fig. 149, *f*), which is often lacking. Inside the anther is a powdery or pasty substance called *pollen* or *microspores* (Sect. 374). The pistil usually consists of a small chamber, the *ovary*, which contains the *ovules*, *macrospores* (Sect. 374), or rudimentary seeds, a slender portion or stalk, called the *style*, and at the top of this a ridge, knob, or point called the *stigma*. These parts are all shown in Fig. 150. In many pistils the stigma is borne directly on the ovary.

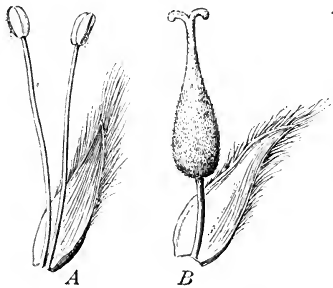


FIG. 143. — Flowers of Willow. (Magnified.)
A, staminate flower; *B*, pistillate flower.

215. Union of Stamens with Each Other. — Stamens may be wholly unconnected with

[1] It would not be safe to assume that the gamosepalous calyx or the gamopetalous corolla is really formed by the union of separate portions, but it is very convenient to speak of it as if it were.

each other or *distinct*, or they may cohere by their filaments into a single group, when they are said to be *monadelphous*, of one brotherhood (Fig. 151), into two groups (*diadelphous*) (Fig. 152), or into many groups. In some flowers the stamens are held together in a ring by their coherent anthers (Fig. 153).

Fig. 144. — Bell-Shaped Corolla of Bell-Flower (*Campanula*).

216. Union of Pistils. — The pistils may be entirely separate from each other, *distinct* and *simple*, as they are in the buttercup and the stonecrop, or several may join to form one *compound pistil* of more or less united carpels. In the latter case the union generally affects the ovaries, but often leaves the styles separate, or it may result in joining ovaries and styles, but leave the stigmas separate or at any rate lobed, so as to show of how many separate carpels the compound pistil is made up. Even when there is no external sign to show the compound nature of the pistil, it can usually be recognized from the study of a cross-section of the ovary.

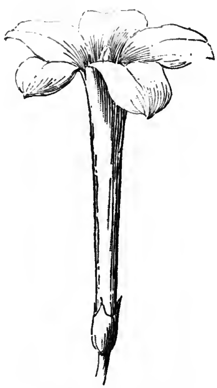


Fig. 145. — Salver-Shaped Corolla of Jasmine. (Magnified.)

Fig. 146. Wheel-Shaped Corolla of Potato.

217. Cells of the Ovary; Placentas. — Compound ovaries are very commonly several-celled, that is, they consist of a number of separate cells[1] or chambers, more scientifically known as *locules.* Fig. 154, *B*, shows a three-celled ovary seen in cross-section. The ovules are not borne indiscriminately by any part of the lining of the ovary. In one-celled pistils they frequently grow in a line running along one side of the ovary, as in the pea pod (Fig. 271). The ovule-bearing line is called a *placenta;* in compound pistils there are commonly as many placentas as there are

Fig. 147.—Tubular Corolla, from Head of Bachelor's Button.

Fig. 148.—Labiate or Ringent Corolla of Dead Nettle.

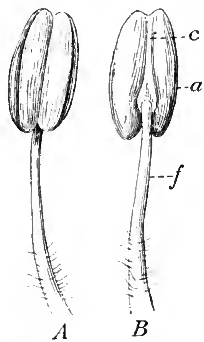


Fig. 149.—Parts of a Stamen.

A, front; *B*, back; *a*, anther; *c*, connective; *f*, filament.

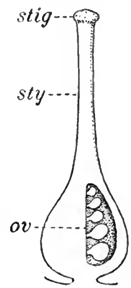


Fig. 150.—Parts of the Pistil.

ov, ovary.
sty, style.
stig, stigma.

separate pistils joined to make the compound one. Placentas on the wall of the ovary, like those in Fig. 154, *A*, are called *parietal placentas;* those which occur as at *B*, in the same figure, are said to be central, and those which, like the form represented in *C* of the same figure, consist of a column rising from the bottom of the ovary are called *free central placentas.*

[1] Notice that the word *cell* is here used in an entirely different sense from that in which it has been employed in the earlier chapters of this book. As applied to the ovary, it means a chamber or compartment.

218. Union of Separate Circles. — The members of one of the circles of floral organs may join those of another circle, thus becoming *adnate*, *adherent*, or *consolidated.*

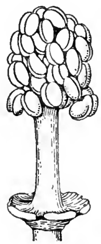


Fig. 151. Monadelphous Stamens of Mallow.

In Fig. 139 the calyx tube is adnate to the ovary. In this case the parts of the flower do not all appear to spring from the receptacle. Fig. 155 illustrates three common cases as regards insertion of the parts of the flower. In I they are all inserted on the receptacle, and the corolla and stamens are said to be *hypogynous*, that is, beneath the pistil. In II the petals and the stamens appear as if they had grown fast to the calyx for some distance, so that they surround the pistil, and they are therefore said to be *perigynous*, that is, around the pistil. In III all the parts are *free* or unconsolidated, except the petals and stamens; the stamens may be described as *epipetalous*, that is, growing on the petals.

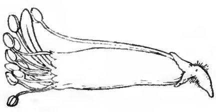


Fig. 152. — Diadelphous Stamens of Sweet Pea.

Sometimes some or all of the other parts stand upon the ovary, and such parts are said to be *epigynous*, that is, on the ovary, like the petals and stamens of the white water-lily (Fig. 156).

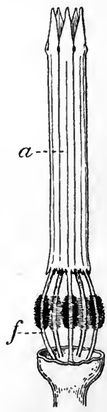


Fig. 153. — Stamens of a Thistle, with Anthers united into a Ring.

a, united anthers; *f*, filaments, bearded on the sides.

219. Floral Diagrams. — Sections (real or imaginary) through the flower lengthwise, like those of Fig. 155, help greatly in giving an accurate idea of the relative position of the floral organs. Still more important in this way are cross-sections, which may be recorded in diagrams like those of Fig. 157.[1] In constructing such diagrams it will often be necessary to suppose some of the parts of the flower to be raised or lowered from their true position, so as to bring them into such relations that all could be cut by a single section. This would, for instance, be necessary in making a diagram for the cross-section of the flower of the white water-lily, of which a partial view of one side is shown in Fig. 156.[2]

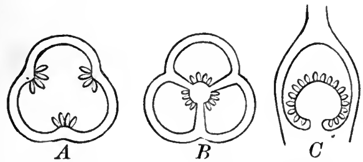


FIG. 154. — Principal Types of Placenta. *A*, parietal placenta; *B*, central placenta; *C*, free central placenta; *A* and *B*, transverse sections; *C*, longitudinal section.

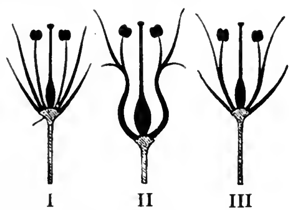


FIG. 155. — Insertion of the Floral Organs.

I, Hypogynous, all the other parts on the receptacle, beneath the pistil; II, Perigynous, petals and stamens apparently growing out of the calyx, around the pistil; III, corolla hypogynous, stamens epipetalous.

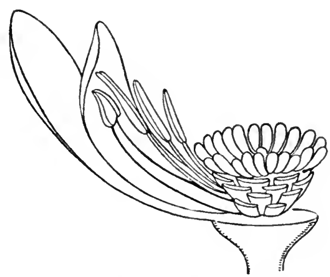
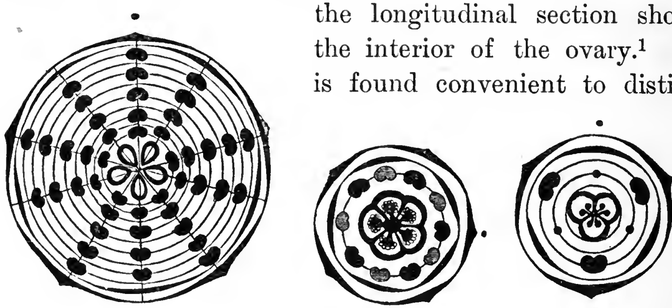


FIG. 156. — White Water-Lily. The inner petals and the stamens growing from the ovary.

[1] For floral diagrams see Le Maout and Decaisne's *Traité Général de Botanique*, or Eichler's *Blüthendiagramme*.

[2] It is best to begin practice on floral diagrams with flowers so firm and large that actual sections of them may be cut with ease and the relations of the parts in the section readily made out. The tulip is admirably adapted for this purpose.

Construct diagrams of the longitudinal section and the transverse section of several large flowers, following the method indicated in Figs. 155 and 157, but making the longitudinal section show the interior of the ovary.[1] It is found convenient to distin-



I II III

Fig. 157. — Diagram of Cross-Sections of Flowers.

I, columbine; II, heath family; III, iris family. In each diagram the dot alongside the main portion indicates a cross-section of the stem of the plant. In II every other stamen is more lightly shaded, because some plants of the heath family have five and some ten stamens.

guish the sepals from the petals by representing the former with midribs. The diagrammatic symbol for a stamen stands for a cross-section of the anther, and that for the pistil is a section of the ovary. If any part is lacking in the flower (as in the case of flowers which have some antherless filaments) the missing or abortive organ may be indicated by a dot. In the diagram of the Iris Family (Fig. 157, III) the three dots inside the flower indicate the position of a second circle of stamens, found in most flowers of monocotyledons but *not* found in this family.

[1] Among the many excellent early flowers for this purpose may be mentioned trillium, bloodroot, dogtooth violet, marsh marigold, buttercup, tulip tree, horse-chestnut, Jeffersonia, May-apple, cherry, apple, crocus, tulip, daffodil, primrose, wild ginger, cranesbill, locust, bluebell.

220. Review Summary of Chapter XV.[1]

Kinds of flowers as regards number of circles or sets of organs present . . . .
1. complete
2. Perfect
3. Incomplete
4. Imperfect

Kinds as regards numerical plan . . . .
1. symmetrical
2. unsym.

Kinds as regards similarity of parts of the same circle . . . .
1. regular
2. irregular

Parts of a stamen . . . .
1. anther
2. filament

Parts of a pistil . . . .
1. ovary
2. style
3. stigma

Stamens as regards union with each other . . .
1. distinct
2. monadelphous
3. diadelphous
4.

Pistils as regards union with each other . . . .
1. simple
2. compound

Degree of union of separate circles . . . . .

[1] Illustrate by sketches.

CHAPTER XVI

TRUE NATURE OF FLORAL ORGANS; DETAILS OF THEIR STRUCTURE; FERTILIZATION

221. The Flower a Shortened and greatly Modified Branch. — In Chapter VIII, the leaf-bud was explained as being an undeveloped branch, which in its growth would develop into a real branch (or a prolongation of the main stem). Now, since flower-buds appear regularly

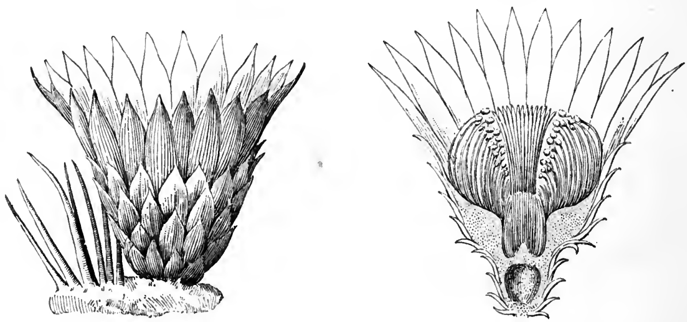


FIG. 158. — Transition from Bracts to Sepals in a Cactus Flower.

either in the axils of leaves or as terminal buds, there is reason to regard them as of similar nature to leaf-buds. This would imply that the receptacle corresponds to the axis of the bud shown in Fig. 86, and that the parts of the flower correspond to leaves. There is plenty of evidence that this is really true. Sepals frequently look very much like leaves, and in many cacti the bracts about the flower are so sepal-like that it is impossible to tell where the bracts end and the sepals begin (Fig. 158). The same thing is true of sepals and petals in such flowers as the white water-lily. In this flower there is a remarkable series of intermediate steps, ranging all the way from petals, tipped with a bit of anther, through stamens with a broad petal-like filament, to regular stamens, as is shown in Fig. 159, *E*, *F*, *G*, *H*. The same thing is shown in

FIG. 159. — Transitions from Petals to Stamens in White Water-Lily. *E*, *F*, *G*, *H*, various steps between petal and stamen.

many double roses. In completely double flowers all the *essential* organs are transformed by cultivation into petals. In the flowers of the cultivated double cherry the pistils occasionally take the form of small leaves, and some roses turn wholly into green leaves.

Summing up, then, we know that flowers are altered and shortened branches: (1) because flower-buds have as regards position, the same kind of origin as leaf-buds; (2) because all the intermediate steps are found between bracts, on the one hand, and stamens, on the other; (3)

because the essential organs are found to be replaced by petals or even by green leaves.

The fact that leaves should be so greatly modified as they are in flowers and given work to do wholly different from that of the other kinds of leaves so far studied need not strike one as exceptional. In many of the most highly developed plants below the seed-plants, organs corresponding to flowers are found, and these consist of modified leaves, set apart for the work of reproducing (Sect. 367).

222. Mode of Formation of Stamens and Pistils from Leaves. — It is hardly possible to state, until after Chapter XXIII has been studied, how stamens stand related to leaves.[1]

The simple pistil or *carpel* is supposed to be made on the plan of a leaf folded along the midrib until its margins touch, like the cherry leaf in Fig. 87. But the student must not understand by this statement that the little pistil leaf grows at first like an ordinary leaf and finally becomes folded in. The united leaf-margins near the tip would form the stigma, and the placenta would correspond to the same margins, rolled slightly inwards, extending along the inside of the inflated leaf-pouch. Place several such folded leaves upright about a common center, and their cross-section would be much like that of *B* in Fig. 154. Evidence that carpels are really formed in this way may be gained from the study of such fruits as that of the monkshood (Fig. 168), in which the ripe carpels may be seen to unfold into a shape much more leaf-like than that which they had while the pistil was maturing. What

[1] "The anther answers exactly to the spore-cases of the ferns and their allies, while the filament is a small specialized leaf to support it." For a fuller statement, see Potter and Warming's *Systematic Botany*, pp. 236, 237.

really occurs is this: the flower-bud, as soon as it has developed far enough to show the first rudiments of the essential organs, contains them in the form of minute knobs. These are developed from the tissues of the plant in the same manner as are the knobs in a leaf-bud, which afterwards become leaves (Fig. 87, II); but as growth and development progress in the flower-bud, its contents soon show themselves to be stamens and pistils (if the flower is a perfect one).

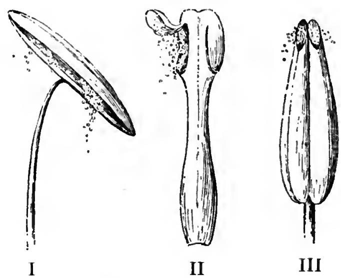


FIG. 160.—Modes of discharging Pollen.

I, by longitudinal slits in the anther-cells (amaryllis); II, by uplifted valves (barberry); III, by a pore at the top of each anther-lobe (nightshade).

223. The Anther and its Contents.—Some of the shapes of the anthers may be learned from Figs. 149 and 160.[1] The shape of the anther and the way in which it opens depend largely upon the way in which the pollen is to be discharged and how it is carried from flower to flower. The commonest method is to have the anther-cells split lengthwise, as in Fig. 160, I. A few anthers open by trap-doors like valves, as in II, and a larger number by little holes at the top, as in III.

The pollen in many plants with inconspicuous flowers, as the evergreen cone-bearing trees, the grasses, rushes, and sedges, is a fine, dry powder. In plants with showy flowers it is often somewhat sticky or pasty. The forms of pollen grains are extremely various. Fig. 161 will serve to furnish examples of some of the shapes which

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 86–95.

the grains assume; *c* in the latter figure is perhaps as common a form as any. Each pollen grain consists mainly of a single cell, and is covered by a moderately thick outer wall and a thin inner one. Its contents are thickish protoplasm, full of little opaque particles and usually containing grains of starch and little drops of oil. The knobs on the outer coat, as shown in Fig. 161 *b*, mark

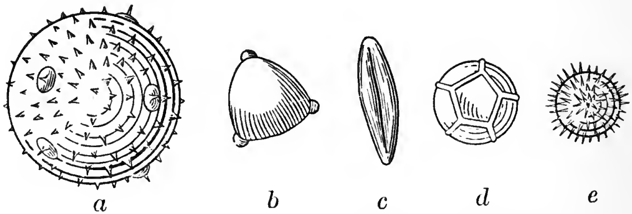


Fig. 161. — Pollen Grains. (Very greatly magnified.)
a, pumpkin; *b*, enchanter's nightshade; *c*, Albuca; *d*, pink; *e*, hibiscus.

the spots at which the inner coat of the grain is finally to burst through the outer one, pushing its way out in the form of a slender, thin-walled tube.[1]

224. The Formation of Pollen Tubes. — This can be studied in pollen grains which have lodged on the stigma and there been subjected to the action of its moist surface. It is, however, easier to cause the artificial production of the tubes.

EXPERIMENT XXXVIII

Production of Pollen Tubes. — Place a few drops of suitably diluted syrup with some fresh pollen in a concave cell ground in a microscope slide; cover with thin glass circle; place under a bell-glass, with a wet cloth or sponge, to prevent evaporation of the syrup, and set aside in a warm place, or merely put some pollen in syrup in a

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 95–104.

watch crystal under the bell-glass. Examine from time to time to note the appearance of the pollen tubes. Try several kinds of pollen if possible, using syrups of various strengths. The following kinds of pollen form tubes readily in syrups of the strengths indicated.

Tulip	1 to 3 per cent.
Narcissus	3 to 5 "
Cytisus canariensis (called Genista by florists)	15 "
Chinese primrose	10 "
Sweet pea [1]	10 to 15 "
Tropæolum [1]	15 "

225. Microscopical Structure of the Stigma and Style. — Under a moderate power of the microscope the stigma is seen to consist of cells set irregularly over the surface, and secreting a moist liquid to which the pollen grains adhere (Fig. 162). Beneath these superficial cells and running down through the style (if there is one) to the ovary is spongy parenchyma. In some pistils the pollen tube proceeds through the cell walls, which it softens by means of a substance which it exudes for that purpose. In other cases (Fig. 163) there is a canal or passage, along which the pollen tube travels on its way to the ovule.

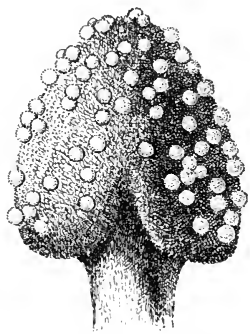


FIG. 162. — Stigma of Thorn-Apple (*Datura*) with Pollen. (Magnified.)

[1] The sweet-pea pollen and that of Tropæolum are easier to manage than any other kinds of which the author has personal knowledge. If a concaved slide is not available, the cover-glass may be propped up on bits of the thinnest broken cover-glasses. From presence of air or some other reason, the formation of pollen tubes often proceeds most rapidly just inside the margin of the cover-glass.

226. Fertilization. — By fertilization in seed-plants the botanist means the union of a generative cell from a pollen grain with that of an egg-cell at the apex of the *embryo sac* (Fig. 165). This process gives rise to a cell which contains material derived from the pollen and from the egg-cell. In a great many plants the pollen, in order to accomplish the most successful fertilization, must come from another plant of the same kind, not from the individual which bears the ovules that are being fertilized.

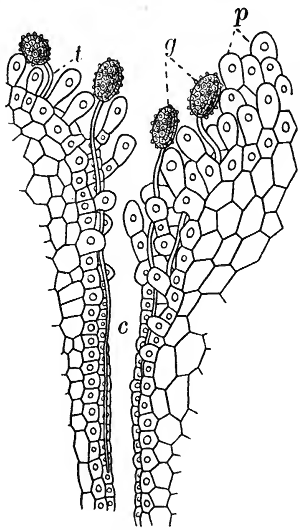


FIG. 163. — Pollen Grains producing Tubes, on Stigma of a Lily. (Much magnified.)

g, pollen grains; *t*, pollen tubes; *p*, papillæ of stigma; *c*, canal or passage running toward ovary.

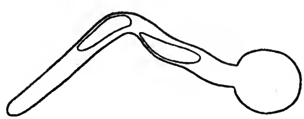


FIG. 164. — Pollen Grain of Snowflake (*Leucoium*) producing a Pollen Tube with Two Naked Generative Cells.

Pollen tubes begin to form soon after pollen grains lodge on the stigma. The time required for the process to begin varies in different kinds of plants, requiring in many cases twenty-four hours or more. The length of time needed for the pollen tube to make its way through the style to the ovary depends upon the length of the style and other conditions. In the crocus, which has a style several inches long, the descent takes from one to three days.

Finally the tube penetrates the opening at the apex of the ovule *m*, in Fig. 165, reaches one of the cells shown at *e*, and transfers a generative cell into this egg-cell. The latter is thus enabled to divide and grow rapidly into an embryo. This the cell does by forming cell-walls and then increasing by continued subdivision, in much the same way in which the cells at the growing point near the tip of the root, or those of the cambium layer, subdivide.[1]

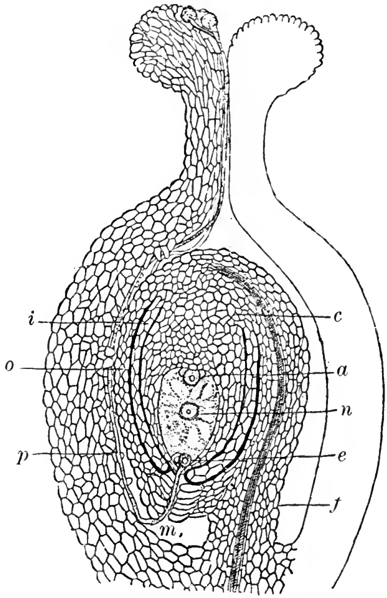


FIG. 165. — Diagrammatic Representation of Fertilization of an Ovule.

i, inner coating of ovule; *o*, outer coating of ovule; *p*, pollen tube, proceeding from one of the pollen grains on the stigma; *c*, the place where the two coats of the ovule blend. (The kind of ovule here shown is inverted, its opening *m* being at the bottom, and the stalk *f* adhering along one side of the ovule.) *a* to *e*, embryo sac, full of protoplasm; *a*, so-called antipodal cells of embryo sac; *n*, central nucleus of the embryo sac; *e*, nucleated cells, one of which, the egg-cell, receives the essential contents of the pollen tube; *f*, funiculus or stalk of ovule; *m*, opening into the ovule.

227. Nature of the Fertilizing Process. — The necessary feature of the process of fertilization is *the union of the essential contents of two cells to form a new one, from which the future plant is to spring.* This kind of union is found to occur in many cryptogams (Chapters XX–XXII), resulting in the production of a spore capable of growing into a complete plant like that which produced it.

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 401–420.

228. Number of Pollen Grains to Each Ovule. — Only one pollen tube is necessary to fertilize each ovule, but so many pollen grains are lost that plants produce many more of them than of ovules. The ratio, however, varies greatly. In the night-blooming cereus there are about 250,000 pollen grains for 30,000 ovules, or rather more than 8 to 1, while in the common garden wistaria there are about 7000 pollen grains to every ovule, and in Indian corn, the cone-bearing evergreens, and a multitude of other plants, many times more than 7000 to 1. These differences depend upon the mode in which the pollen is carried from the stamens to the pistil.

CHAPTER XVII

THE STUDY OF TYPICAL FRUITS

229. A Berry, the Tomato.[1] — Study the external form of the tomato, and make a sketch of it showing the persistent calyx and peduncle.

Cut a cross-section at about the middle of the tomato. Note the thickness of the epidermis (peel off a strip) and of the wall of the ovary. Note the number, size, form, and contents of the cells of the ovary. Observe the thickness and texture of the partitions between the cells. Sketch.

Note the attachments of the seeds to the placentas and the gelatinous, slippery coating of each seed.

The tomato is a typical berry, but its structure presents fewer points of interest than are found in some other fruits of the same general character, so the student will do well to spend a little more time on the examination of such fruits as the orange or the lemon.

230. A Hesperidium, the Lemon. — Procure a large lemon which is not withered, if possible one which still shows the remains of the calyx at the base of the fruit.

Note the color, general shape, surface, remains of the calyx, knob at portion formerly occupied by the stigma. Sketch the fruit about natural size. Examine the pitted surface of the rind with the magnifying glass and sketch it. Remove the bit of stem and dried-up calyx from the base of the fruit; observe, above the calyx, the knob or *disk* on which the pistil stood. Note with the magnifying glass and count the minute whitish raised knobs at the bottom of the saucer-shaped depression left by the removal of the disk. What are they?

[1] Fresh tomatoes, not too ripe, are to be used, or those which have been kept over from the previous summer in formalin solution. The very smallest varieties, such as are often sold for preserving, are as good for study as the larger kinds.

Make a transverse section of the lemon, not more than a fifth of the way down from the stigma end and note:

(1) The thick skin, pale yellow near the outside, white within.

(2) The more or less wedge-shaped divisions containing the juicy pulp of the fruit. These are the matured cells of the ovary; count these.

(3) The thin partition between the cells.

(4) The central column or axis of white pithy tissue.

(5) The location and attachment of any seeds that may be encountered in the section.

Make a sketch to illustrate these points, comparing it with Fig. 171.

Study the section with the magnifying glass and note the little spherical reservoirs near the outer part of the skin, which contain the oil of lemon which gives to lemon peel its characteristic smell and taste. Cut with the razor a thin slice from the surface of a lemon peel, some distance below the section, and at once examine the freshly cut surface with a magnifying glass to see the reservoirs, still containing oil, which, however, soon evaporates. On the cut surface of the pulp (in the original cross-section) note the tubes in which the juice is contained. These tubes are not cells, but their walls are built of cells. Cut a fresh section across the lemon, about midway of its length and sketch it, bringing out the same points which were shown in the previous one. The fact that the number of ovary cells in the fruit corresponds with the number of minute knobs in the depression at its base is due to the fact that these knobs mark the points at which fibro-vascular bundles passed from the peduncle into the cells of the fruit, carrying the sap by which the growth of the latter was maintained.

Note the toughness and thickness of the seed-coats. Taste the kernel of the seed.

Cut a very thin slice from the surface of the skin, mount in water, and examine with a medium power of the microscope. Sketch the cellular structure shown and compare it with the sketch of the corky layer of the bark of the potato tuber.

Of what use to the fruit is a corky layer in the skin? (See Sect. 453 for further questions.)

231. A Legume, the Bean-Pod.[1] — Lay the pod flat on the table and make a sketch of it, about natural size. Label *stigma*, *style*, *ovary*, *calyx*, *peduncle*.

Make a longitudinal section of the pod, at right angles to the plane in which it lay as first sketched, and make a sketch of the section, showing the partially developed seeds, the cavities in which they lie, and the solid portion of the pod between each bean and the next.

Split another pod, so as to leave all the beans lying undisturbed on one-half of it and sketch that half, showing the beans lying in their natural position and the *funiculus* or stalk by which each is attached to the *placenta;* compare Fig. 271.

Make a cross-section of another pod, through one of the beans, sketch the section, and label the placenta (formed by the united edges of the pistil leaf) and the midrib of the pistil leaf.

Break off sections of the pod and determine, by observing where the most stringy portions are found, where the fibro-vascular bundles are most numerous.

Examine some ripe pods of the preceding year,[2] and notice where the *dehiscence*, or splitting open of the pods, occurs, whether down the placental edge, *ventral suture*, the other edge, *dorsal suture*, or both.

232. An Akene, the Fruit of Dock. — Hold in the forceps a ripe fruit of any of the common kinds of dock,[3] and examine with the magnifying glass. Note the three dry, veiny, membranaceous sepals by which the fruit is enclosed. On the outside of one or more of the sepals is found a tubercle or thickened appendage which looks like a little seed or grain. Cut off the tubercles from several of the fruits, put these, with some uninjured ones, to float in a pan of water, and watch their behavior for several hours. What is apparently the use of the tubercle?

[1] Any species of bean (*Phaseolus*) will answer for this study. Specimens in the condition known at the markets as "shell-beans" would be best, but these are not obtainable in spring. Ordinary "string-beans" will do.

[2] Which may be passed round for that purpose. They should have been saved and dried the preceding autumn.

[3] *Rumex crispus*, *R. obtusifolius*, or *R. verticillatus*. This should have been gathered and dried the preceding summer.

Of what use are the sepals, after drying up? Why do the fruits cling to the plant long after ripening?

Carefully remove the sepals and examine the fruit within them. What is its color, size, and shape? Make a sketch of it as seen with the magnifying glass. Note the three tufted stigmas, attached by slender threads to the apex of the fruit. What does their tufted shape indicate?

What evidence is there that this seed-like fruit is not really a seed?

Make a cross-section of a fruit and notice whether the wall of the ovary can be seen, distinct from the seed-coats. Compare the dock fruit in this respect with the fruit of the buttercup, shown in Fig. 166. Such a fruit as either of these is called an *akene*.

CHAPTER XVIII

THE FRUIT[1]

233. What constitutes a Fruit. — It is not easy to make a short and simple definition of what botanists mean by the term *fruit.* It has very little to do with the popular use of the word. Briefly stated, the definition may be given as follows: *The fruit consists of the matured ovary and contents, together with any intimately connected parts.* Botanically speaking, the bur of beggar's ticks (Fig. 273), the three-cornered grain of buckwheat, or such true grains as wheat and oats, are as much fruits as is an apple or a peach.

The style or stigma sometimes remains as an important part of the fruit in the shape of a hook, as in the common hooked crowfoot; or in the shape of a plumed appendage, as in the virgin's bower, often called wild hops. The calyx may develop hooks, as in the agrimony, or plumes, as in the thistle, the dandelion, lettuce, and many other familiar plants. In the apple, pear, and very many berries, the calyx becomes enlarged and pulpy, often constituting the main bulk of the mature fruit. The receptacle not infrequently, as in the apple, forms a more or less important part of the fruit.

234. Indehiscent and Dehiscent Fruits. — All of the fruits considered in the next three sections are *indehiscent*,

[1] See Gray's *Structural Botany*, Chapter VII, also Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 427–438.

that is, they remain closed after ripening. *Dehiscent* fruits when ripe open in order to discharge their seeds. The three classes which immediately follow Sect. 237 belong to this division.

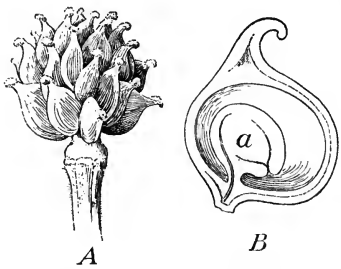


FIG. 166.— Akenes of a Buttercup. *A*, head of akenes ; *B*, section of a single akene (magnified) ; *a*, seed.

235. The Akene. — The one-celled and one-seeded pistils of the buttercup, strawberry, and many other flowers, ripen into a little fruit called an *akene* (Fig. 166). Such fruits, from their small size, their dry consistency, and the fact that they never open, are usually taken for seeds by those who are not botanists.

In the group of plants to which the daisy, the sunflower, and the dandelion belong, the akenes consist of the ovary and the adherent calyx tube. The limb of the calyx is borne on the summit of many akenes, sometimes in the form of teeth, sometimes as a tuft of hairs or bristles (Fig. 267).

236. The Grain. — Grains, such as corn, wheat, oats, barley, rice, and so on, have the interior of the ovary completely filled by the seed, and the seed-coats and the wall of the ovary are firmly united, as shown in Fig. 6.

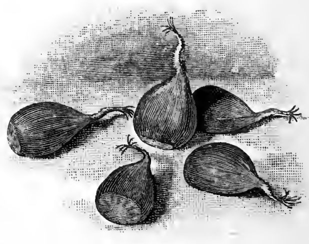


FIG. 167.—Chestnuts.

237. The Nut. — A nut (Fig. 167) is larger than an akene, usually has a harder shell, and commonly contains a seed which springs from a single ovule of one cell of a compound ovary, which develops at the expense of all the other ovules. The chestnut-bur is a kind of involucre, and so is the acorn-cup. The name *nut* is often incorrectly applied in popular language; for example, the so-called Brazil-nut is really a large seed with a very hard testa.

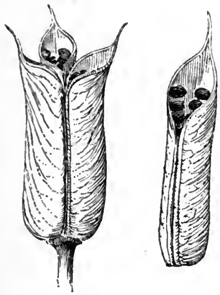


FIG. 168. — Group of Follicles and a Single Follicle of the Monkshood.

238. The Follicle. — One-celled, simple pistils, like those of the marsh marigold, the columbine, and a good many other plants, often produce a fruit which dehisces along a single suture, usually the ventral one. Such a fruit is called a *follicle* (Fig. 168).

239. The Legume. — A legume is a one-celled pod, formed by the maturing of a simple pistil, which dehisces along both of its sutures, as already seen in the case of the bean pod, and illustrated in Fig. 271.

240. The Capsule. — The dehiscent fruit formed by the ripening of a compound pistil is called a *capsule*. Such a fruit may be one-celled, as in the linear pod of the celandine (Fig. 271), or several-celled, as in the fruit of the poppy, the morning-glory, and the jimson weed (Fig. 271).

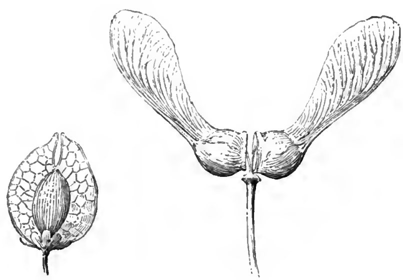


FIG. 169. — Winged Fruits.
I, elm ; II, maple.

241. Dry Fruits and Fleshy Fruits. — In all the cases discussed or described in Sects. 238–240, the wall of the ovary (and the adherent calyx when present) ripen into tissues which are somewhat hard and dry. Often, however, these parts become developed into a juicy or fleshy mass by which the seed is surrounded; hence a general division of fruits into *dry fruits* and *fleshy fruits*.

242. The Stone-Fruit. — In the peach, apricot, plum, and cherry, the *pericarp* or wall of the ovary, during the process of ripening, becomes converted into two kinds of tissue, the outer portion pulpy and edible, the inner portion of almost stony hardness. In common language the hardened inner layer of the pericarp, enclosing the seed, is called the *stone* (Fig. 170), hence the name *stone-fruits*.

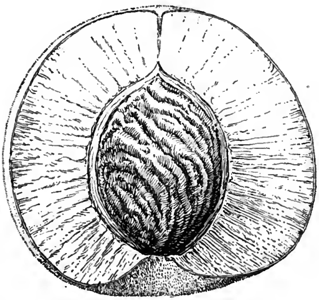


FIG. 170. — Peach. Longitudinal Section of Fruit.

243. The Pome. — The fruit of the apple, pear, and quince is called a *pome*. It consists of a several-celled ovary, — the seeds and the tough membrane surrounding them in the *core*, — enclosed by a fleshy, edible portion which makes up the main bulk of the fruit and is formed from the much-thickened calyx, with sometimes an enlarged receptacle. In the apple and the pear much of the fruit is receptacle.

244. The Pepo or Gourd-Fruit. — In the squash, pumpkin, and cucumber, the ripened ovary, together with the thickened adherent calyx, makes up a peculiar fruit (with a firm outer rind) known as the *pepo*. The relative bulk of enlarged calyx and of ovary in such fruits is not always the same.

How does the amount of material derived from fleshy and thickened placentæ in the squash compare with that in the watermelon?

245. The Berry. — The berry proper, such as the tomato, grape, persimmon, gooseberry, currant, and so on, consists of a rather thin-skinned, one- to several-celled, *fleshy ovary* and its contents. In the first three cases above mentioned the calyx forms no part of the fruit, but it does in the last two, and in a great number of berries.

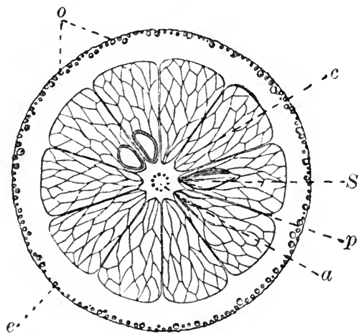


FIG. 171. — Cross-Section of an Orange.
a, axis of fruit with dots showing cut-off ends of fibro-vascular bundles; *p*, partition between cells of ovary; *S*, seed; *c*, cell of ovary, filled with a pulp composed of irregular tubes, full of juice; *o*, oil reservoirs near outer surface of rind; *e*, corky layer of epidermis.

The gourd-fruit and the *hesperidium*, such as the orange (Fig. 171), lemon, and lime, are merely decided modifications of the berry proper.

246. Aggregate Fruits. — The raspberry, blackberry (Fig. 172), and similar fruits consist of many carpels, each of which ripens into a part of a compound mass, which, for a time at least, clings to the receptacle. The whole is called an *aggregate fruit.*

To which one of the preceding classes does each unit of a blackberry or of a raspberry belong?

What is the most important difference in structure between a fully ripened raspberry and a blackberry?

247. Accessory Fruits and Multiple Fruits. — Not infrequently, as in the strawberry (Fig. 172), the main bulk of the so-called fruit consists neither of the ripened ovary nor its appendages. Such a combination is called an *accessory fruit.*

Examine with a magnifying glass the surface of a small, unripe strawberry, then that of a ripe one, and finally a section of a ripe one, and decide where the separate fruits of the strawberry are found, what kind of fruits they are, and of what the main bulk of the strawberry consists.

The fruits of two or more separate flowers may blend into a single mass, which is known as a *multiple fruit.* Perhaps the best-known edible examples of this are the

I II III

Fig. 172. — I, Strawberry; II, Raspberry; III, Mulberry.

mulberry (Fig. 172) and the pineapple. The last-named fruit is an excellent instance of the seedless condition which not infrequently results from long-continued cultivation.

248. Summary. — The student may find it easier to retain what knowledge he has gained in regard to fruits if he copies the following synopsis of the classification of fruits, and gives an example of each kind.

- Fruits
  - Composition
    - Simple.
    - Aggregate.
    - Accessory.
    - Multiple.
  - Texture
    - Fleshy
      - 1.
      - 2.
      - 3.
    - Stone
    - Dry
      - 1.
      - 2.
      - 3.
      - 4.
  - Mode of disseminating seed
    - Indehiscent
      - 1.
      - 2.
      - 3.
    - Dehiscent
      - 1.
      - 2.
      - 3.

CHAPTER XIX

THE CLASSIFICATION OF PLANTS[1]

249. Natural Groups of Plants. — One does not need to be a botanist in order to recognize the fact that plants naturally fall into groups which resemble each other pretty closely, that these groups may be combined into larger ones the members of which are somewhat alike, and so on. For example, all the bulb-forming spring buttercups[2] which grow in a particular field may be so much alike in leaf, flower, and fruit that the differences are hardly worth mentioning. The tall summer buttercups[3] resemble each other closely, but are decidedly different from the bulbous spring-flowering kind, and yet are enough like the latter to be ranked with them as buttercups. The yellow water-buttercups[4] resemble in their flowers the two kinds above mentioned, but differ from them greatly in habit of growth and in foliage, while still another, a very small-flowered kind,[5] might fail to be recognized as a buttercup at all.

The marsh marigold, the hepatica, the rue anemone, and the anemone all have a family resemblance to buttercups,[6] and the various anemones by themselves form another group like that of the buttercups.

[1] See Warming and Potter's *Systematic Botany*, Strasburger, Noll, Schenk, and Schimper's *Text-Book of Botany*, Part II, or Kerner and Oliver, Vol. II, pp. 616–790. [2] *R. bulbosus.* [3] *R. acris.* [4] *R. multifidus.* [5] *R. abortivus.*
[6] Fresh specimens or herbarium specimens will show this.

250. Genus and Species. — Such a group as that of the buttercups is called a *genus* (plural *genera*), while the various kinds of buttercups of which it is composed are called *species*. The scientific name of a plant is that of the genus followed by that of the species. The generic name begins with a capital, the specific does not, unless it is a substantive. After the name comes the abbreviation for the name of the botanist who is authority for it; thus the common elder is *Sambucus canadensis*, L., L. standing for Linnæus. Familiar examples of genera are the Violet genus, the Rose genus, the Clover genus, the Golden-rod genus, the Oak genus. The number of species in a genus is very various, — the Kentucky Coffee-tree genus contains only one species, while the Golden-rod genus comprises more than forty species in the northeastern United States alone.

251. Hybrids. — If the pollen of a plant of one species is placed on the stigma of a plant of the same genus but a different species, no fertilization will usually occur. In a large number of cases, however, the pistil will be fertilized, and the resulting seed will often produce a plant intermediate between the two parent forms. This process is called *hybridization*, and the resulting plant a *hybrid*. Many hybrid oaks have been found to occur in a state of nature, and hybrid forms of grapes, orchids, and other cultivated plants, are produced by horticulturists at will.

252. Varieties. — Oftentimes it is desirable to describe and give names to subdivisions of species. All the cultivated kinds of apple are reckoned as belonging to one species, but it is convenient to designate such varieties as the

Baldwin, the Bellflower, the Rambo, the Gravenstein, the Northern Spy, and so on. Very commonly varieties do not, as horticulturists say, "come true," that is to say, the seeds of any particular variety of apple not only are not sure to produce that variety, but they are nearly sure to produce a great number of widely different sorts. Varieties which will reproduce themselves from the seed, such as pop-corn, sweet corn, flint-corn, and so on, are called *races*.

Only long and careful study of plants themselves and of the principles of classification will enable any one to decide on the limits of the variety, species, or genus, that is, to determine what plants shall be included in a given group and what ones shall be classed elsewhere.

253. Order or Family. — Genera which resemble each other somewhat closely, like those discussed in Sect. 249, are classed together in one order or family. The particular genera above mentioned, together with a large number of others, combine to make up the Crowfoot family. In determining the classification of plants most points of structure are important, but the characteristics of the flower and fruit outrank others because they are more constant, since they vary less rapidly than the characteristics of roots, stems, and leaves do under changed conditions of soil, climate, or other surrounding circumstances. Mere size or habit of growth has nothing to do with the matter, so the botanist finds no difficulty in recognizing the strawberry plant and the apple tree as members of the same family.

This family affords excellent illustrations of the meaning of the terms *genus*, *species*, and so on. Put in a tabular form, some of the subdivisions of the Rose family are as follows :

The Rose family includes (among many others) :	Plum genus	Peach species (many varieties).	
		Garden plum species (many varieties).	
		Wild black cherry species.	
		Garden red cherry species (many varieties).	
	Rose genus	Dwarf wild rose species.	
		Sweet-brier species.	
		India rose species	Tea variety.
			Pompon variety, etc.
		Damask rose species.	
	Pear genus	Pear species	Seckel variety.
			Bartlett variety.
			Sheldon variety, etc.
		Apple species	Baldwin variety.
			Greening variety.
			Bellflower variety.
			Northern Spy variety, etc.

254. Grouping of Families. — Families are assembled into *classes*, and these again into larger *groups*. The details of the entire plan of classification are too complicated for any but professional botanists to master, but an outline of the scheme may be given in small space.

The entire vegetable kingdom is divided into two great divisions, the first consisting of *cryptogams* or spore-plants, the second of *phanerogams* or seed-plants. Here the relations of the various subdivisions may best be shown by a table.[1]

[1] This is, of course, only for consultation, not to be committed to memory.

255. Table of the Classification of the Vegetable Kingdom.

DIVISION I CRYPTOGAMS OR SPORE-PLANTS	GROUP I MYXOTHALLOPHYTES or *plasmodial plants*	CLASS	*Myxogasteres*, Common slime-fungi.
	GROUP II THALLOPHYTES or *leafless cellular cryptogams*[1]	CLASS 1.	*Schizomycetes*, Bacteria.
		" 2.	*Schizophyceæ*, Fission-plants.
		" 3.	*Bacillariales*, Diatoms.
		" 4.	*Conjugatæ*, Desmids and pond-scums.
		" 5.	*Chlorophyceæ*, Green algæ.
		" 6.	*Phæophyceæ*, Brown algæ.
		" 7.	*Rhodophyceæ*, Red algæ.
		" 8.	*Phycomycetes*, Moulds, etc.
		" 9.	*Basidiomycetes*, Mildews, rusts, and toadstools.
		" 10.	*Ascomycetes*, Yeasts, truffles, etc.
		COLLATERAL CLASS.	*Lichenes*: Algæ and fungi leading a life in partnership, the combination known as a *lichen*.
	GROUP III BRYOPHYTES or *moss-like plants*	CLASS 1.	*Hepaticæ*, Liverworts.
		" 2.	*Musci*, True mosses.
	GROUP IV PTERIDOPHYTES or *fern-like plants*	CLASS 1.	*Filicales*, Ferns.
		" 2.	*Equisetales*, Scouring rushes.
		" 3.	*Lycopodiales*, Club mosses.

[1] Classes 3–7 inclusive of the thallophytes are often placed in a subgroup known as *algæ*, and 8–10 inclusive in another subgroup, *fungi*.

DIVISION II PHANEROGAMS OR SEED-PLANTS	CLASS I GYMNOSPERMS or *seed-plants with naked ovaries*, such as pines, spruces, cedars, and many other evergreen trees.	
	CLASS II ANGIOSPERMS or *seed-plants with closed ovaries*	SUBCLASS I MONOCOTYLEDONOUS PLANTS SUBCLASS II DICOTYLEDONOUS PLANTS

256. The Groups of Cryptogams. — The student is not to suppose that the arrangement of cryptogams into the four great groups given in the preceding table is the only way in which they could be classed. It is simply one way of dividing up the enormous number of spore-bearing plants into sections, each designated by marked characteristics of its own. But the amount of difference between one group and another is not always necessarily the same. The pteridophytes and the bryophytes resemble each other much more closely than the latter do the thallophytes, while the myxothallophytes are but little like other plants and it is extremely probable that they are really animals.

The classes given in the table do not embrace all known cryptogams, but only those of which one or more representatives are described or designated for study in this book. Lichens in one sense hardly form a class, but it is most convenient to assemble them under a head by themselves, on account of their extraordinary mode of life, a partnership between algæ and fungi.

257. The Classes of Seed-Plants. — The gymnosperms are much less highly developed than other seed-plants.

The angiosperms constitute the great majority of seed-plants (or, as they have been more commonly called, flowering plants). Only one family of gymnosperms (the *Coniferæ*) is described in Part III of this book, though there are other families of great interest to the botanist, but with no representatives growing wild in the Northern United States.

When people who are not botanists speak of plants they nearly always mean angiosperms. This class is more interesting to people at large than any other, not only on account of the comparatively large size and the conspicuousness of the members of many families, but also on account of the attractiveness of the flowers and fruit of many. Almost all of the book which precedes the present chapter (except Chapter XII) has been occupied with seed-plants.

Seed-plants of both classes frequently offer striking examples of adaptation to the conditions under which they live, and these adaptations have lately received much study, and are now treated as a separate department of botany (see Part II).

CHAPTER XX

TYPES OF CRYPTOGAMS; THALLOPHYTES

258. The Group Thallophytes. — Under this head are classed all the multitude of cryptogams which have a plant-body without true roots, stems, or leaves. Such a plant-body is called a *thallus*. In its simplest form it consists of a portion of protoplasm not enclosed in a cell-wall and without much of any physiological division of labor among its parts (Fig. 125). Only a little less simple are such enclosed cells as that of *Pleurococcus* (Sect. 278) or one of the segments of *Oscillatoria* (Sect. 268). The most complex thallophytes, such as the higher algæ and fungi, have parts definitely set aside for absorption of food and for reproduction. The latter is sometimes accomplished by more than one process and is occasionally aided by some provision for scattering the reproductive bodies or *spores* about when they are mature.

259. Spores. — Before beginning the study of spore-plants it is well for the student to know what a spore is. *A spore is a cell which becomes free and capable of developing into a new plant.* Spores are produced in one of two ways: either *asexually*, from the protoplasm of some part of the plant (often a specialized spore-producing portion), or *sexually*, by the combination of two masses of protoplasm, from two separate plants, or from different parts of the same plant.

Asexually produced spores are sometimes formed, each by the condensation of the protoplasm of a single cell, as shown in Fig. 174, *E*. They are also formed by the contents of spore-cases breaking up into many spores (Fig. 173, *B*; Fig. 210, *D*). Spores are sometimes produced by the spontaneous division of a mass of protoplasm into a small definite number of segments (Fig. 188, *t*). Spores which have the power of moving (swimming) freely are known as *zoöspores* (Fig. 179, *B*).

Sexually produced spores are formed in many ways. One of the simplest modes is that shown in Fig. 178, resulting in *zygospores*. Other methods are illustrated in Figs. 185 and 187.[1]

THE STUDY OF SLIME MOULDS[2]

260. Occurrence. — Slime moulds occur in greenhouses, in tan-yards, or on old logs and decaying leaves in woods. They may be cultivated in the laboratory.

They have been described in their vegetative condition on page 179.

261. Examination with the Magnifying Glass. — *Stemonitis* is one of the most available genera to illustrate the fruiting of slime moulds. At maturity the motile protoplasm of the vegetative stage quickly transforms itself into numerous sporangia or spore-cases with dust-like spores. With the naked eye and with a magnifying glass note the color, form, and feathery appearance of the spore-case of *Stemonitis*. The outer wall disappears at an early stage, leaving only an inner structure and spores. Sketch the general outline under a magnifying glass.

262. Examination with the Microscope. — With a low power of the microscope sketch the network of branching hairs which compose the structure of the sporangium. Note the presence or absence

[1] See Vine's *Student's Text-Book of Botany*, pp. 68–71.

[2] This should logically precede Sect. 258.

of a central column. Have any of the branches free tips? With a power of 250 or more examine the spores. A much higher power may be used to advantage. Describe the surface of the spore.

THE STUDY OF BACTERIA

263. Occurrence. — "Bacteria may occur anywhere but not everywhere." In water, air, soil, and almost any organic substance, living

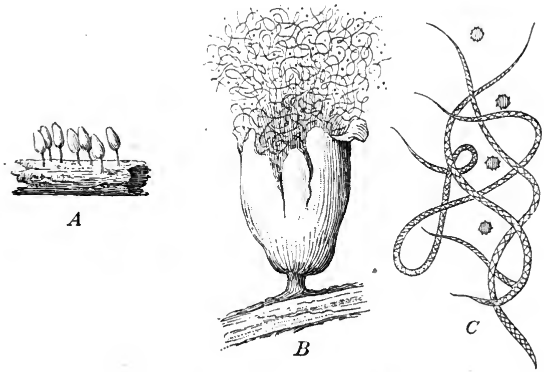


FIG. 173. — Spore-Cases of Slime Moulds.

A, a group of spore-cases of *Arcyria*; *B*, a spore-case of *Trichia*, bursting open and exposing its spores to the wind, × 20; *C*, threads of the same, with spores between them, × 250.

or dead, some species of plant belonging to the group *Bacteria* may occur. A small bunch of hay placed in a tumbler of water will, at a suitable temperature, yield an abundant crop in a few days or hours. Raw peas or beans soaked for a week or two in water in a warm place will afford a plentiful supply.

264. Cultures. — Pure cultures of bacteria are commonly made in some preparation of gelatine in sterilized test-tubes. Boiled potatoes serve a good purpose for simple (but usually not pure) cultures.

Select a few small roundish potatoes with skins entire and boil in water for a sufficient time to cook them through. Cut them in halves with a knife well scalded or *sterilized*, *i.e.*, freed from all living organisms in a flame, and lay each on a saucer, with cut surface up, covering each with a glass tumbler. The tumblers and saucers should be well scalded or kept in boiling water for half an hour and used without wiping. Sterilization may be improved by baking them in an oven for an hour.

265. Inoculation. — The culture media prepared as above may now be inoculated. Uncover them only when necessary and quickly replace the cover. Scrape a little material from the teeth, tongue, kitchen sink, floor of house or schoolroom, or any other place you may desire to investigate. With the point of a knife blade or a needle sterilized in a flame, inoculate a particle of the material to be cultivated into the surface of one of the potatoes. Several cultures

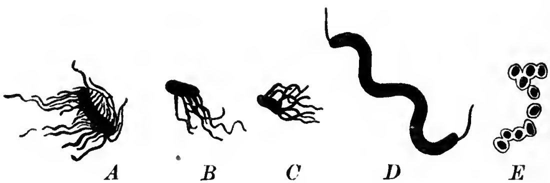


FIG. 174. — Bacteria stained to show Cilia.

A, *Bacillus subtilis*; *B*, *Bacillus typhi* (the bacillus of typhoid fever); *C*, *Bacillus tetani* (the bacillus which causes lockjaw); *D*, *Spirillum undula*; *E*, *Bacillus tetani* forming spores. (All five are magnified 1000 diameters.)

may be made in this way and one or more left uninoculated as checks. Another may be left uncovered in the air for half an hour. Others may be made with uncovered potatoes. Number each culture and keep a numbered record.

Keep watch of the cultures, looking at them daily or oftener. As soon as any change is noticed on the surface of a culture, make a descriptive note of it and continue to record the changes which are seen. Note the color of the areas of growth, their size, outline, elevation above the surface, and any indications of wateriness. Any growth showing peculiar colors or other characters of special interest may be inoculated into freshly prepared culture media, using any additional precautions that are practicable to guard against contamination.

266. Microscopic Examination. — Examine some of the cultures. Place a particle of the growth on a slide, dilute it with a drop of clear water, and place a cover-glass over it. Examine with the highest obtainable power of the microscope, at least $\frac{1}{6}$ in. objective. Note the forms and movements, also the sizes if practicable, of any bacteria that are found.

THE STUDY OF OSCILLATORIA[1]

267. Occurrence. — *Oscillatoria* may occur floating in stagnant water or on damp soil in ditches, roadsides, dooryards, paths, or pots in greenhouses. Other nearly related plants occur on surfaces of ponds sometimes covering considerable areas or adhering in small spheres to submerged vegetation. Algæ of this class are particularly noxious in water supplies, as they partake of the nature of bacteria, to which they are related.

268. Examination with the Microscope. — After washing a particle of *Oscillatoria* material in a drop of water to remove as much of the earth as possible, place it in a clean drop of water, pull to shreds with needles, cover, and examine under a power of 200 or more diameters.

Note the color and compare it with chlorophyll green.

The filament is not one plant, but each of the cells which compose it is one plant. They are packed together in the filament like coins and sometimes may be found separating singly. The usual mode of reproduction is by the separation of a number of adhering cells as a short filament from one end of a longer one, and this increases in length by the dividing of its individual cells.

269. Movement. — At ordinary temperatures, favorable to growth, movement may be observed in the filaments. Describe the movement. What has it to do with the name of the plant?

[1] A genus of the class *Schizophyceæ*.

THE STUDY OF DIATOMS

270. Occurrence. — Diatoms of different species may be found in sediment in water in various kinds of places or mixed with or adhering to fresh-water or marine algæ, in ponds and ditches or on sand or earth at the bottom of clear brooks. In the last place they may be detected with the eye, forming a yellowish coloring. They may often be obtained by straining hydrant water. Where diatoms have been very abundant their remains sometimes form beds of rock, and fossil diatoms compose some of the polishing powders of commerce.

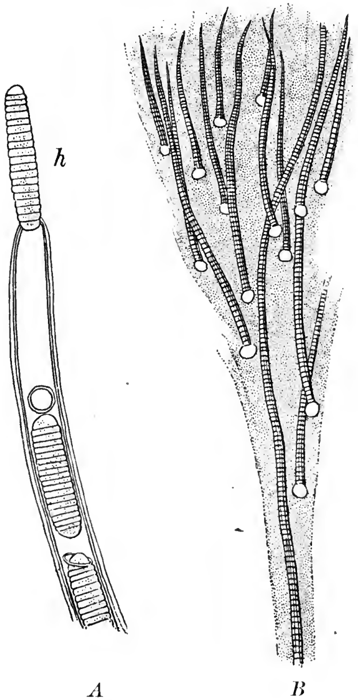


FIG. 175. — *Schizophyceæ*.
A, a filament of *Calothrix*, reproducing by *hormogonia*, *h*, segmented portions which escape from the sheath of the filament; *B*, *Rivularia*. (Both *A* and *B* greatly magnified.)

271. Microscopical Examination of Diatoms. — Place a drop of water containing diatoms on a slide and put a cover-glass over it. Examine with a power of 200 or more diameters. Diatoms occur singly, resembling triangles, wheels, boats, rods, and a great variety of other forms (Fig. 176), or adhering in long bands, as spokes of a wheel, etc. The boat-shaped kinds are among the commonest. The color of the contents is yellowish. The cell-wall is encrusted with a shell of silica whose surface is covered with beautiful markings, dots or lines, which are conspicuous in some species, in others so minute that the most powerful microscopes are required to detect them. By boiling in nitric acid, the cellulose wall and its contents may be destroyed and the markings of the siliceous shell more easily observed. Each diatom consists of a single cell.

272. Movements of Diatoms. — Living diatoms exhibit a peculiar power of movement. In the boat-shaped species the movement is much like that of a row-boat, forward or backward.

THE STUDY OF SPIROGYRA

273. Occurrence. — *Spirogyra*, one of the plants commonly known as pond-scum, or "frog-spit," occurs widely distributed throughout the country in ponds, springs, and clear streams. It is of a green or yellowish-green color, and in sunny weather usually floats on or near the surface of the water, buoyed up by the numerous oxygen bubbles which it sets free. It may be found flourishing in unfrozen springs, even in midwinter.

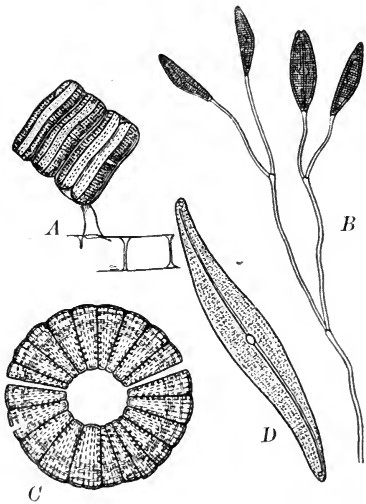


FIG. 176. — A Group of Diatoms.
A, Achnanthes; B, Cocconema; C, Meridion; D, Pleurosigma.

274. Examination with the Magnifying Glass.[1] — Float a little of the material in a white plate, using just water enough to cover the bottom of the latter. Study with the magnifying glass and note the green color of the threads and their great length as compared with their thickness. Are all the filaments about equal to each other in diameter?

Handle a mass of the material and describe how it feels between the fingers.

275. Examination with the Microscope. — Mount in water under a large cover-glass and examine first with a power of about 100

[1] Consult Huxley's *Biology* and Spalding's *Introduction to Botany*.

diameters, then with a power of 200 diameters or more. Note the structure of the filaments. Of what is each made up? Compare with the structure of *Oscillatoria*.

Move the slide so as to trace the whole length of several filaments, and, if the unbroken end of one can be found, study and sketch it.

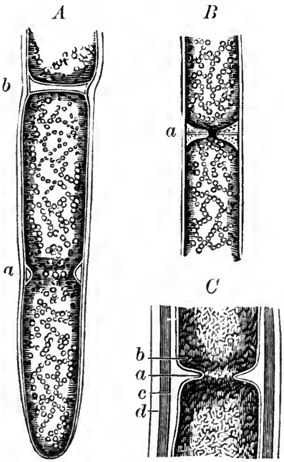


FIG. 177. — Process of Cell-Multiplication in a Species of Pond-Scum. (Considerably magnified.)

A, portion of a filament partly separated at *a* and completely so at *b*; *B*, separation nearly completed, a new partition of cellulose formed at *a*; *C*, another portion more magnified, showing mucous covering *d*, general cell-wall *c*, and a delicate membrane *a*, which covers the cell-contents *b*.

Study with the higher power a single cell of one of the larger filaments and ascertain the details of structure. Try to discover, by focusing, the exact shape of the cell. How do you know that the cells are not flat? Count the bands of chlorophyll. The number of bands is an important characteristic in distinguishing one species from another.

Run in five-per-cent salt solution at one edge of the cover-glass (withdrawing water from the other edge with a bit of blotting paper). If any change in the appearance of the cell becomes evident, make a sketch to show it. What has happened to the cell-contents? Explain the cause of the change by reference to what you know of osmose.

On a freshly mounted slide run under the cover-glass iodine solution, a little at a time, and note its action on the nucleus. Is any starch shown to be present? If so, just how is it distributed through the cell?

276. Reproduction of Spirogyra. — The reproductive process in *Spirogyra* is of two kinds, the simplest being a process of *fission*, or cell-division. The nucleus undergoes a very complicated series of transformations, which result in the division of the protoplasmic contents of a cell into two independent portions, each of which is at length surrounded by a complete cell-wall of its own. In Fig. 176

the division of the protoplasm and formation of a partition of cellulose in a kind of pond-scum are shown, but the nucleus and its changes are not represented.

Another kind of reproduction, namely by *conjugation*, is found in *Spirogyra*. This process in its simplest form is found in such unicellular plants as the desmids (Fig. 178). Two cells (apparently precisely alike) come in contact, undergo a thinning-down or absorptive process in the cell-walls at the point of contact, and finally blend their protoplasmic cell-contents, as shown in the figure, to form a mass known as a *spore*, or more accurately a *zygospore*, from which, after

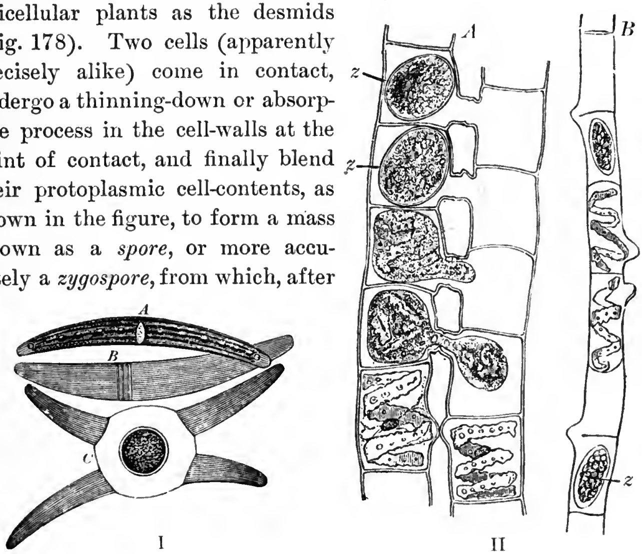


FIG. 178.—Conjugation of Cells of Green Algæ. (Much magnified.)

I. Conjugation of Desmids. *A*, a single plant in its ordinary condition; *B*, empty cell-wall of another individual; *C*, conjugation of two individuals to form a spore by union of their cell-contents.

II. Conjugation of *Spirogyra*. *A*, two filaments of *Spirogyra* side by side, with the contents of adjacent cells uniting to form spores, *z*. At the bottom of the figure the process is shown as beginning at the top as completed, and the cells of one filament emptied; *B*, a single filament of another kind of *Spirogyra*, containing two spores, one lettered *z*. (*A* magnified 240 diameters, *B* 150 diameters.)

a period of rest, a new individual develops. In *Spirogyra* each cell of the filament appears to be an individual and can conjugate like the one-celled desmids. It is not easy to watch the process, since the spore-formation takes place at night. It is possible, however, to retard the occurrence of conjugation by leaving the *Spirogyra* filaments in very cold water over night, and in this way the successive steps of the conjugating process may be studied by daylight. In such ways the series of phenomena shown in Fig. 178, II, has been accurately followed. If the student cannot follow these operations under the microscope, he may, at least, by looking over the yellower portions of a mass of *Spirogyra* find threads containing fully formed zygospores, like those shown in *B*, Fig. 178.

THE STUDY OF PLEUROCOCCUS

277. Occurrence. — *Pleurococcus* may be found on old fences, roofs, and many similar places, particularly on the bark of the north side of trees. The individual plants cannot be detected by the naked eye, but when grouped in masses they form a powdery green covering over indefinite areas of bark. Plenty are seen where it is moist.

278. Microscopical Examination of Pleurococcus. — Scrape a minute quantity of *Pleurococcus* from a specimen on bark, place it in a drop of water on a slide, distributing it slightly in the water, lay on it a cover-glass and examine with a power of 200 or more diameters. Sketch with the *camera lucida* one of the largest cells, some of intermediate size, and one of the smallest, beside several divisions of the stage micrometer.

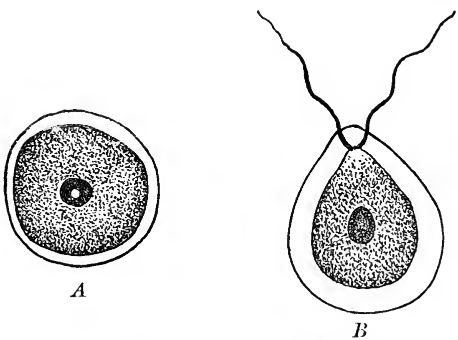


FIG. 179. — Two Cells of *Protococcus*. (Greatly magnified.)

A, a spherical cell of the still form; *B*, a motile cell with its protoplasm enclosed in a loose cell-wall and provided with two cilia.

Note the clearly defined cell-wall of cellulose, enclosing the protoplasmic contents, usually green throughout. Do any cells show a nucleus like that in Fig. 179, *A*?

Test the cells with iodine solution for starch.

Note that in reproduction the cell-contents in many individuals has divided into two parts which become separated from each other by a cellulose partition. Each of these again divides, and the process continues until thirty-two or more cells may be found in one mass or they may fall apart at an earlier stage.

279. Nutrition of Pleurococcus. — *Pleurococcus* can flourish only with an abundance of light and moisture. In daylight it can absorb carbon dioxide and fix carbon (giving off the oxygen at the same time as bubbles of oxygen) and can assimilate mineral substances. It is a capital example of an individual cell capable of independent existence.

280. Motile Forms. — No motile form is known in *Pleurococcus. Hæmatoccus*, often known as *Protococcus* (Fig. 179), is a better object for study than *Pleurococcus.* It may sometimes be found in water of stagnant pools, particularly those which contain the drainage of barnyards or manure-heaps, in mud at the bottom of eaves-troughs, in barrels containing rain-water, or in water standing in cavities in logs or stumps. Its presence is indicated by a greenish or sometimes by a reddish color. It is sometimes found in an actively swimming condition, in which case each cell is called a *zoöspore.*

THE STUDY OF VAUCHERIA

281. Occurrence. — Species of *Vaucheria* are found in ponds, streams, and pools, immersed or floating like *Spirogyra* and at all seasons may be sought in greenhouses, where they grow on the moist earth of beds and pots, forming a green felt.

282. Examination with the Magnifying Glass. — The magnifying glass will show the growth of *Vaucheria* to consist of numerous green filaments similar to those of *Spirogyra.* Select a small portion and spread out the filaments carefully in a drop of water on a slide. Does the glass reveal any indications of cross-partitions, of branching, or of fruiting organs as short lateral branches? Does it show the form or arrangement of the green coloring matter?

283. Examination with the Microscope. — Prepare as directed for the magnifying glass and place a cover-glass over the preparation, with sufficient water. With the lowest power observe the continuity of the cell-cavity and (in young plants growing on soil) search for root-like portions, in those growing in water for branching portions, and fruiting organs in the form of swellings or short lateral branches.

With a power of about thirty to sixty diameters sketch a selected plant of moderate extent as nearly complete as possible or else

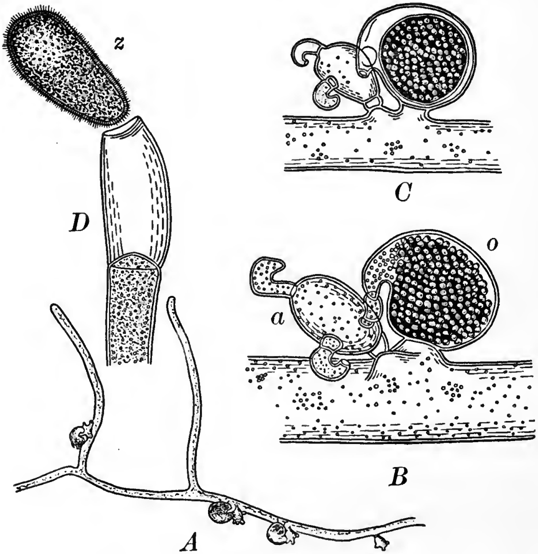


FIG. 180. — *Vaucheria synandra.*

A, a filament with archegonia and antheridia (considerably magnified); *B*, part of same much more highly magnified; *o*, oögonium; *a*, antheridium; *C*, a later stage of *B*; *D*, end of a filament with a zoöspore, *z*, escaping (highly magnified).

sketch a portion showing the branching and a root-like portion. Note and indicate the absence or presence and arrangement of chlorophyll. Can *Vaucheria* probably use carbon dioxide?

284. Reproduction in Vaucheria. — Make an outline sketch of fruiting organs, if found. See if any filaments can be found with the contents massing or escaping at the tips. In some species zoöspores are formed in this way, having their entire surface clothed with cilia. They are the largest motile cells known. In other species a portion of the filament is separated and cut off by a cell-wall. Such spores soon germinate and may be found in various stages of growth. They often serve for propagation through several generations before spores are produced by fertilization.

With a power of about 200 diameters sketch a portion of a filament to show the form and location of chlorophyll. Sketch the fruiting organs in detail, if any can be found.[1]

Antheridia and oögonia are formed near together on the same filament. The antheridium is a cell forming the terminal portion of a short branch, which is rather slender, straight or curved. Its contents form numerous minute antherozoids, each with two cilia. The cilia can be seen only with great difficulty, if at all, but their presence is indicated by their active movements.

The oögonium is a short, somewhat spheroidal branch separated by a cross-partition at the base. The cell-wall becomes ruptured at the tip, allowing the entrance of the antherozoids by which it is fertilized. After fertilization a cell-wall is formed about the oösphere, and it matures as an oöspore and enters upon a period of rest.

THE STUDY OF NITELLA

285. Occurrence. — *Nitella* is a green plant growing attached to the bottom of ponds and streams, usually in shallow water. It is not common everywhere but is widely distributed. *Chara* is similar and may be used as a substitute but is more complicated.

286. General Aspect. — With the naked eye and a magnifying glass note the general aspect of *Nitella*, the length of the stem-like portions, from the root-like parts to the tip, the length of some of the joints (internodes), the arrangement of leaf-like and branch-like portions.

287. Protoplasm. — Examine the cells of stems or leaves under a low power. Select a vigorous cell of moderate size and examine

[1] Goebel states that the formation of the fruiting organs begins in the evening, is completed the next morning, and that fertilization takes place during the day between ten and four o'clock.

under a power of 200 or more diameters. Select the terminal cell of the leaf if *Chara* is used. The protoplasm is nearly colorless but usually contains bodies which can be seen moving in the current of protoplasm. The protoplasm will show normal activity at the temperature of a comfortable living room. By focusing, see if the current of protoplasm can be detected moving in more than one direction.

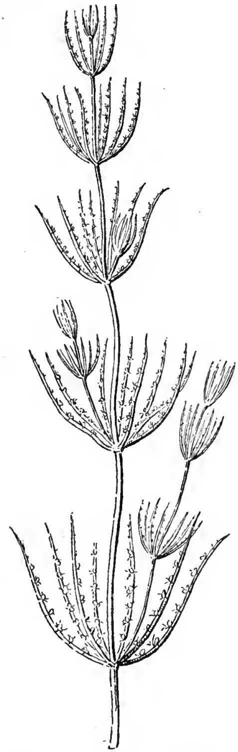


FIG. 181. — End of a Main Shoot of *Chara*. (About natural size.)

Note the form and arrangement of the chlorophyll and any places lacking chlorophyll, and see if you can tell whether the arrangement has any relation to the current of protoplasm. With a low power trace the course in several cells. How many cells constitute each internode of *Nitella?* If *Chara* is used, internodes will be found to be covered with a layer of many corticating cells. Under a high power compare the general structure of node and internode and see if the attachment of leaves and branches can be clearly determined. Compare the tip of a leaf with the tip of a stem or branch if the material permits. Are the fruiting organs produced on the stems or the leaves?

288. Antheridia. — The antheridia are globular bodies, bearing male fertilizing cells and becoming red at maturity (Fig. 182). Eight cells compose the outer wall. They have radial lines indicating folds and join one another by irregular sutures. Note a round spot in the middle of each cell which marks the point of attachment within of the stalk on which antherozoid-producing cells are borne.

289. Oögonia. — The egg-shaped fruits, known as *oögonia* (Fig. 182), are borne near the antheridia in monœcious species. Count the number of pointed cells which constitute the "crown" of the fruit. Does each tip consist of one or two short cells? Examine the surface of the enveloping cells which enclose the spore. What is their number and form? What is their relation to the cells forming the crown? Focus so as to see the large egg-cell (*oösphere* or *oöspore*) which constitutes the center of the fruit. Can you determine anything regarding its contents?

Search for young oögonia and if practicable describe and draw them in several stages of development. Their structure can be seen much more easily than that of the antheridia. Make drawings to illustrate various details of structure.

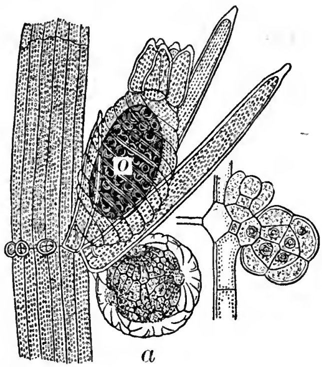


FIG. 182. — Part of a Leaf of Fig. 181. (Considerably magnified.) *a*, antheridium; *o*, oögonium. At the right are a young antheridium and archegonium.

290. Characeæ. — *Nitella* and *Chara* are the genera composing the group *Characeæ*, a group of green algæ differing widely from any others. They show in a wonderful manner simplicity of cell-structure with a high degree of organization. Scarcely less wonderful are the care and precision with which botanists have worked out their life history. As a study in evolution the *Characeæ* may be considered as representing the highest development attained along the line of filamentous green algæ, which, while preserving their algal characteristics, are comparable in a remarkable degree with moss- and fern-plants and with seed-plants. Every cell in the plant has been accounted for and is understood in regard to origin, relationship, and function. With harmony of structure throughout, it has organs comparable to root, stem, and leaf in seed-plants, each with characteristic structure and mode of growth. The stem has nodes and internodes. The stem increases by the growth of an apical cell, but growth in length depends chiefly on the elongation of each internodal cell instead of the multiplication of numerous internodal cells.

THE STUDY OF ROCKWEED[1]

291. Occurrence. — The common rockweed is abundant everywhere on rocks, between high and low tide, on the New England coast and southward.

FIG. 183. — Part of Thallus of a Rockweed (*Fucus platycarpus*), natural size. The two uppermost branchlets are fertile.

292. The Frond. — A plant of rockweed consists mostly of a growth which is somewhat leaf-like, but, in fact, stem and leaf are not separately developed, and the growth is therefore called a *thallus*. This combined stem and leaf has many flat leathery branches which are buoyed up in the water by air-bladders. Cut one of the bladders open and note its form and appearance. Note whether they occur singly or how grouped. Note the prominent midrib running throughout the middle of each branch. Examine the swollen tips of some of the branches and note their peculiarities. Sketch a portion of a frond to show the characteristics so far noted.

293. Reproduction. — Cut across through the middle of one of the swollen fruiting tips. Note the fruiting papillæ (*conceptacles*) as they appear in this section, and make a simple sketch to show their position.

Select some plants with brighter colored tips and some less bright, if any difference

[1] *Fucus vesiculosus* is the most available species. Others may be substituted.

can be detected. After making the microscopic examination which follows, note what correspondence of structure with color has been observed. Cut very thin sections through fruiting tips from different plants, keeping those from each plant separate. Be sure that some of the cuts pass through the conceptacle as near the middle as possible.

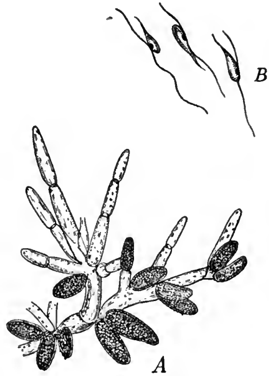


FIG. 184.—Rockweed (*Fucus*). *A*, antheridia borne on branching hairs, × 160; *B*, antherozoids from same, × 330.

Examine with a power of about sixty diameters sections from different fronds, searching for one kind containing rather large egg-shaped cells and another containing bundles of numerous smaller sac-shaped cells. With a power of 200 diameters study the details of the sections. Note the character of the cells forming the surface of the frond, those of the inner structure, and those limiting the cavity of the conceptacle. In a conceptacle cut through the middle note the form of the orifice. Examine the slender hairs or filaments (*paraphyses*) which, arising at right angles, line the walls of the conceptacle.

294. Oögonia and Antheridia. — In conceptacles containing egg-shaped cells (*oögonia*) note the form, mode of attachment (sessile or stalked), and different stages of development. At maturity the contents are divided, forming eight oöspheres; but not all can be seen at once, some being beneath the others.

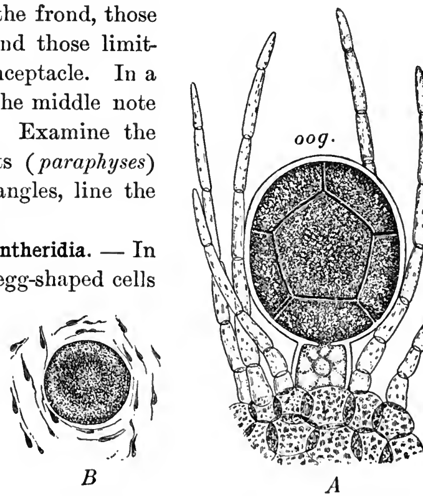


FIG. 185.—Rockweed (*Fucus*). *A*, oögonium, its contents dividing into eight oöspheres, × 160; *B*, an oösphere, escaped, surrounded by antherozoids, × 160.

In conceptacles of the other kind examine the numerous small sac-shaped cells (*antheridia*). At maturity the contents of each divide to form numerous very minute motile *antherozoids*, each with two delicate hairs or cilia. Dissect, by picking and by friction under cover-glass, a bunch of antheridia and note the branching filaments upon which they are borne.

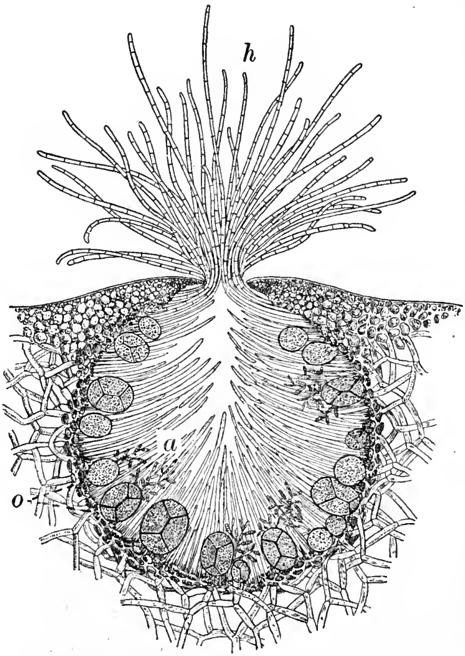


FIG. 186.—Transverse Section of Conceptacle of a Rockweed (*Fucus platycarpus*). (× about 35.)
h, hairs ; *a*, antheridia ; *o*, oögonia.

Make drawings to illustrate the various points of structure.

295. Number of Antherozoids required for Fertilization.—The bulk of an oösphere has been estimated equal to that of thirty thousand to sixty thousand antherozoids, but apparently an oösphere may be fertilized by only one antherozoid. Yet a large number swarm around each oösphere after both have escaped from the conceptacles, and often their movements are so active as to cause the rotation of the oösphere. The process of fertilization may be discerned in fresh material by squeezing oöspheres and antherozoids from their respective conceptacles into a drop of water on a slide. In some species, as *Fucus platycarpus* (Fig. 186), antheridia and oögonia are found in the same conceptacle.

THE STUDY OF NEMALION

296. Occurrence. — Seven or eight species of *Nemalion* are known in the world, but only one[1] is widely diffused, being found in Europe and on the New England coast from Rhode Island northward. It grows in salt water attached to exposed rocks at low-water mark. *Nemalion* represents the largest of the groups of algæ, nearly all of which live in salt water and have the characteristic color; but a few live in fresh water.

297. Color. — Fresh specimens or those properly dried for the herbarium show the color which is characteristic of the great group to which *Nemalion* belongs. Dried specimens of "Irish moss" (*Chondrus*) and many other species furnish good illustrations. There are many variations of shade and intensity.

Place a piece of a fresh or dried specimen of some species in a beaker of fresh water over night or longer and note the color of the solution and of the treated specimen. Treat another piece similarly with alcohol. A few genera related to *Nemalion* grow in fresh water. What do you infer regarding their color?

298. Form and General Character. — Examine specimens of *Nemalion* and note the size, shape, mode of branching, nature, or consistency of their substance. Examine a fragment of the plant with a power of about sixty diameters and note how the structure differs from what it appears to be to the naked eye. Do cells appear more densely packed or differently colored at any points?

299. Structure. — From a small portion of the plant cut thin longitudinal and transverse sections or pull it to pieces with needles so as to expose the inner portion. Place on a slide under a cover-glass in a drop of water. With a power of about 250 diameters or more examine the general structure of the frond, as shown by a slide prepared as above. Note the central portion (*axis*) of the frond as dissected out, consisting of long, slender, thread-like cells. Examine and draw the branching rows of cells which, radiating from the axis, form the surrounding outer structure of the frond. Note the tips of these branches and look for the fruiting organs and fruit (*spores*).

[1] *Nemalion multifidum.*

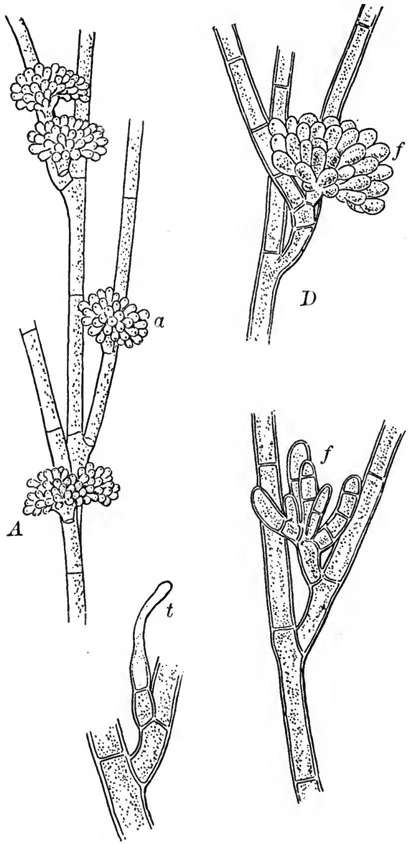


FIG. 187.—Portions of Thallus of a Red Alga (*Chantransia*). (Much magnified.)

A, filaments with antheridia, *a*; *B*, young receptive hair, or *trichogyne*, *t*; *C* and *D*, successive stages in the growth of the clustered fruit, *f*.

300. Organs for Reproduction. — The fruiting organs are to be sought on the radiating branching filaments and are usually produced in great abundance during the summer. Various stages of development may be expected at a given time. The antherozoids are small spheres without cilia, non-motile, with a thin cell-wall. Look for cells in which they are formed (*antheridia*), occurring in groups at the tips of the branches. Compare these with the vegetative cells.

301. Spore-Production. — Look for spore-producing organs in various stages. In the young stage at the time of fertilization, antherozoids, carried by currents of water, may be found adhering. Note the shape of the tip (*trichogyne*) and the base (*carpogonium*), and find whether there is any partition separating them at this stage. Draw or describe a few later stages in development, and note the arrangement of the spores at maturity. Are they naked or enclosed in any sort of envelope? Are they arranged in masses, chains, or otherwise?

302. Other Florideæ. — *Nemalion* represents one of the simplest modes of fruiting in the red algæ. In others there is great variety in structure and great complication in the mode of fruiting. Some species of *Polysiphonia* (or *Dasya*) may well be studied in comparison with *Nemalion* and in further illustration of this important group.[1] Understanding that a siphon, in algæ, is a row of cells, end to end, study the structure of a plant of *Polysiphonia* as illustrating its name. How many siphons are there? Do the main branches have any other cells covering the surface (corticating cells)?

Note the tufts of repeatedly forking, one-siphoned filaments.

303. Fruiting of Polysiphonia. — The antheridia are to be sought on the branching filaments just mentioned. Note how they differ from those of *Nemalion*. The clustered fruits or *cystocarps* will be recognized as ovoid-globose or urn-shaped bodies attached externally to the frond. Note whether the group of spores is naked or otherwise, whether the spores are produced singly or in chains; how attached; shape.

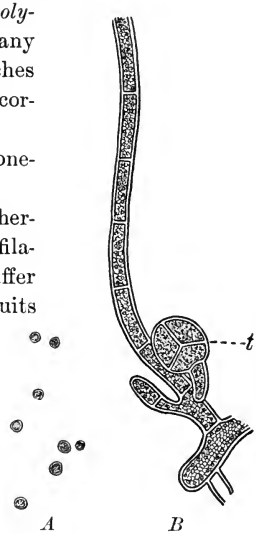


FIG. 188.

A, spores of *Nemalion* (greatly magnified); *B*, portion of thallus of a red alga, *Lejolisia*, with tetraspores, *t*.

Many *Florideæ* have another kind of fruiting bodies, spores produced without fertilization, coördinate with the asexual spores of black mould (see Sect. 308). In *Florideæ* such spores are usually found in fours and are called *tetraspores*.

Are tetraspores usually found on separate plants?

In *Polysiphonia* the tetraspores appear to be formed in threes (*tripartite*), the fourth being underneath the three. When found, describe their position and arrangement.

304. Algæ. — *Diatom*, *Oscillatoria*, *Pleurococcus*, *Spirogyra*, *Vaucheria*, *Nitella*, *Fucus*, *Nemalion*, these eight

[1] It is desirable also to exhibit fresh or pressed specimens of various genera to show their general aspect.

plants which we have just studied, are types of several families of plants which together make the great group called *Algæ*. Something of its importance in nature is indicated by these facts: The number of known species is about 12,000. In size, the individuals in various species range from a single cell of microscopic dimensions, as in *Pleurococcus*, to the giant kelp of California which reaches a length of more than 1000 feet. The form ranges from a simple spherical cell as in *Pleurococcus* to an extensive, branching cell in *Vaucheria* and its allies, specialized organs in the form of root, stem, leaf, air-bladder, and fruiting organs in *Sargassum*, which is an ally of *Fucus*.

The algæ illustrate a series of modes of propagation from simple division in *Oscillatoria* to the union of two similar masses of protoplasm to form a spore in *Spirogyra*, the direct fertilization of a germ-cell by motile antherozoids in *Vaucheria*, *Nitella*, *Fucus*, the indirect fertilization of fruiting cells by non-motile antherozoids in *Nemalion*. In allies of the latter there are more intricate variations of the same mode.

The algæ fall into five natural groups based primarily on the mode of fruiting. In most cases color is coördinate with class and may be relied upon as a superficial guide in grouping; but there are a few exceptions, *e.g.*, some fruiting like the red group are, nevertheless, green.

The nutrition of the brown and the red algæ is similar to that of the green algæ, since the brown or red color merely conceals the green of the chlorophyll which is present in all and enables them all to take in and decompose carbon dioxide.[1]

[1] See Murray's *Introduction to the Study of Seaweeds*, pp. 4–6. London, 1895.

305. Classification of Types studied.

DIATOMACEÆ. *Diatoms.*	Yellowish.
CYANOPHYCEÆ. *Oscillatoria.*	Blue-green or some similar color.
CHLOROPHYCEÆ. *Pleurococcus, Spirogyra, Vaucheria, Nitella.*	Green.
PHÆOPHYCEÆ. *Fucus.*	Olive.
FLORIDEÆ. *Nemalion. Polysiphonia.*	Red.

THE STUDY OF BLACK MOULD (RHIZOPUS NIGRICANS)

306. Occurrence. — This mould may be found in abundance on decaying fruits, such as tomatoes, apples, peaches, grapes, and cherries, or on decaying sweet potatoes or squashes. For class study it may most conveniently be obtained by putting pieces of wet bread on plates for a few days under bell-jars and leaving in a warm place until patches of the mould begin to appear.

307. Examination with the Magnifying Glass. — Study some of the larger and more mature patches and some of the smaller ones. Note:

(*a*) The slender, thread-like network with which the surface of the bread is covered. The threads are known as *hyphæ*, the entire network is called the *mycelium*.

(*b*) The delicate threads which rise at intervals from the mycelium and are terminated by small globular objects. These little spheres are spore-cases. Compare some of the spore-cases with each other and notice what change of color marks their coming to maturity.

308. Examination with the Microscope. — Sketch a portion of the untouched surface of the mould as seen (opaque) with a two-inch objective, then compare with Fig. 189.

Wet a bit of the mould, first with alcohol, then with water. Examine in water with the half-inch objective, and sketch a little of the mycelium, some of the spore-cases, and the thread-like stalks on which they are borne. Are these stalks and the mycelium filaments solid or tubular? Are they one-celled or several-celled?

Mount some of the mature spore-cases in water, examine them with the highest obtainable power, and sketch the escaping spores.

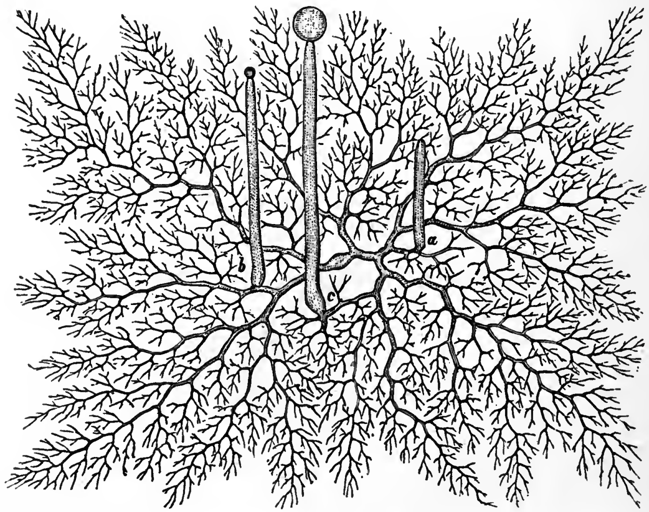


FIG. 189. — Unicellular Mycelium of a Mould (*Mucor Mucedo*), sprung from a Single Spore.

a, *b*, and *c*, branches for the production of spore-cases, showing various stages of maturity. (Considerably magnified.)

Sow some of these spores on the surface of "hay-tea," made by boiling a handful of hay in just water enough to cover it and then straining through cloth or filtering through a paper filter. After from three to six hours examine a drop from the surface of the liquid with a medium power of the microscope (half-inch objective) to see how the development of hyphæ from the spores begins. Sketch.

After about twenty-four hours examine another portion of the mould from the surface of the liquid and study the more fully developed mycelium. Sketch.

309. Zygospores. — Besides the spores just studied, *zygospores* are formed by conjugation of the hyphæ of the black moulds. It is not very easy to find these in process of formation, but the student may be able to gather from Fig. 190 the nature of the process by which they are formed, — a process which cannot fail to remind him of the conjugation of pond-scum.

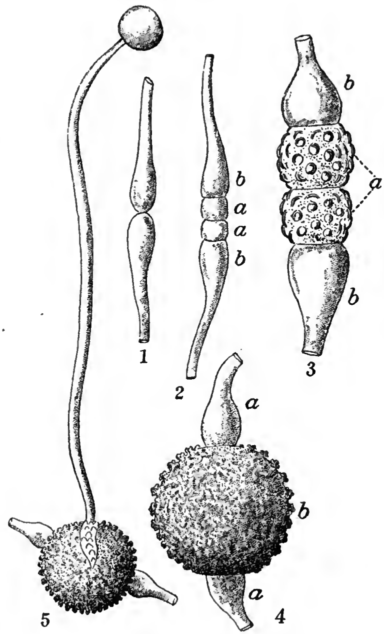


FIG. 190. — Formation of Zygospores in a Mould (*Mucor Mucedo*).

1, threads in contact previous to conjugation; 2, cutting off of the conjugating cells, *a*, from the threads, *b*; 3, a later stage of the process; 4, ripe zygospore; 5, germination of a zygospore and formation of a spore-case. (1–4 magnified 225 diameters, 5 magnified about 60 diameters.)

THE STUDY OF WHEAT RUST (PUCCINIA GRAMINIS)

310. Occurrence. — Wheat rust is common on cultivated wheat and other grains, and also on many wild and cultivated forage grasses. In fact, this or similar rusts occur on a very large number of grasses, and many species of such rusts are recognized. A rust may have one, two, or three kinds of spores, and when three occur one is known as the *cluster-cup stage* and the others as *red rust* and *black rust*, according to the usual approximate color of the spores. The rust called *Puccinia graminis* growing on wheat has its cluster-cup stage on the leaves of barberry in June. The spores from the cluster-cups are carried by the wind to the wheat, where they germinate and in a few days produce the red rust. A little later the black spores appear, produced from the same mycelium. This growth is chiefly upon the stems and sheaths.

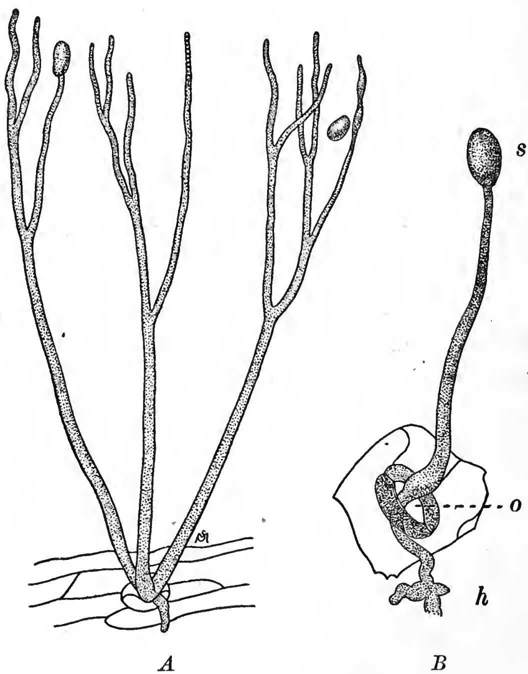


FIG. 191. — Spore-Formation in Potato-Blight (*Phytophthora infestans*).

A, a well-developed group of stalks, proceeding from a mass of mycelium inside the leaf and escaping through a stoma; *B*, a young, unbranched stalk. *h*, hyphæ of mycelium; *o*, stoma; *s*, spore. (Both figures greatly magnified, *B* more than *A*.)

311. Cluster-Cup Stage. — Note with the naked eye and with a magnifying glass the appearance of the cluster-cups upon the barberry leaf. Fresh specimens should be used, if available. Note whether the leaf is changed in form or color in any part occupied by the fungus. Note the number of cups in a cluster, the position on the leaf (which surface?), the form and size, especially the height.

Are they straight or curved? Describe the margin of the cup, the color without, and the color of the contents.

With a power of 200 diameters or more examine some of the cells composing the cup and note the form, color, and nature of the surface. Draw. With the point of a needle or knife pick out a bit of the contents of the cup and examine as above. Note the characters as before and compare in detail with the cells of the cup. The cells within the cup are the spores. Can you tell how they are attached?

A thin section through the cup will show the mode of attachment and the relation of the spores to the cup.

312. Examination of Red and Black Rust. — Under the magnifying glass examine the eruptions of spores (*sori*) on the wheat plant, some of red spores and some of black spores. The red spores are faded in dried specimens. Note the approximate size and shape and any other peculiarities. Prepare slides of each kind of spores and see if both can be found in one sorus. The spores may be taken from the host-plant on the point of a knife by picking rather deeply down into the sorus. Place the small quantity of spores so

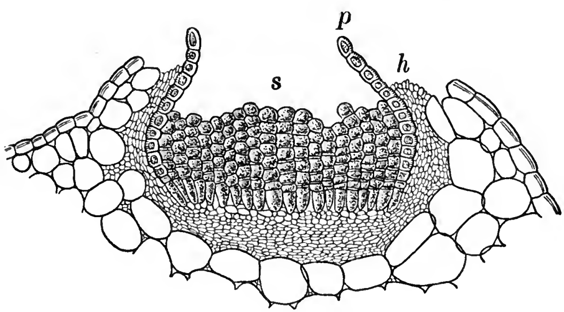


FIG. 192. — A Cluster-Cup of Anemone Rust (*Puccinia fusca*). (× 120.) *s*, chains of spores; *p*, the covering or peridium of the cup; *h*, hyphæ.

obtained in a drop of water on a slide, spread with dissecting needles and cover. Examine under a power of 200 or more diameters.

The red spores (*uredospores*) have each a stalk from which they easily fall. They may be seen attached to their stalks if properly prepared cross-sections through the sorus are available, especially if the material is fresh. Examine the spores and note the shape, color, and surface. If the spores are shrunken, a drop of potash solution will restore the natural plumpness. Draw. Spore-measurements are important in determining species. The *uredospores* of *Puccinia graminis* may be distinguished from those of other species common on grasses by the greater proportionate length.

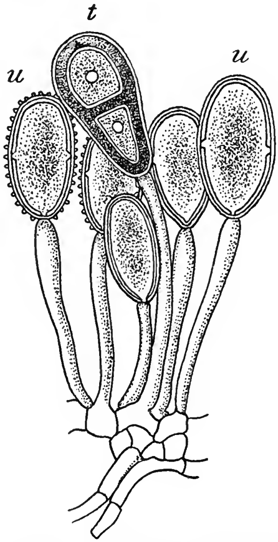


FIG. 193.—A Group of Spores of Wheat Rust (*Puccinia graminis*). (× about 440.) *u*, *u*, uredospores; *t*, a teleutospore.

The structure of the black spores (*teleutospores*) can be made out without difficulty. Some should be found attached at the base. Note the parts and the differences in color in different portions. Make careful drawings to show shape and structure of both kinds of spores.

Boil a portion of a rust-injured plant in potash solution, pick it to pieces on a slide under the magnifier or dissecting microscope, use a cover-glass and examine the preparation for mycelium, using a high power.

313. Cultivation on a Host-Plant. — If practicable, find some wheat or grass which has remained over winter with the black rust upon it. Tie a bunch of this to a barberry bush while the leaves are young or unexpanded. When the time arrives for the appearance of the cluster-cups, note whether they are any more abundant on this bush than on others. Are you sure that the rust you have is the one to which the barberry cluster-cups belong?

THE STUDY OF MICROSPHÆRA

314. Occurrence. — Species of *Microsphæra* and allied forms occur in late summer and fall on leaves of various herbaceous and woody plants. The growth is confined to the surfaces of the leaf (upper, lower, or both). Among the most available species are those which grow upon lilac, oak, grape, cherry, willow, and wild plants of the sunflower family. Some species are known to occur on only one host-plant, others occur on several or a large number, and the host-plants may belong to one or more than one family.

Besides *Microsphæra* there are about five other genera, any of which may be substituted or studied comparatively. They are distinguished by the form of the appendages, together with the number of spore-sacs (*asci*) in each sac-receptacle or *perithecium*.

The species of fungi which *Microsphæra* represents are called *powdery mildews*.

With naked eye and magnifying glass examine the surface of a leaf bearing powdery mildew. Note which surface and what portion of the surface is occupied by the fungus, whether the occupied area is restricted or not, the color, and any other characters.

315. Examination with the Microscope. — Place a small drop of water on the leaf where the fungus occurs, if possible where dark-colored specks occur among the mycelium. Pick from the leaf a portion of the fungus loosened by the water and place with a drop of water on a slide. Place a cover-glass over it. Examine under a power of about fifty diameters. The dark-colored specks will be seen as somewhat spherical bodies (*perithecia*). Note their structure and color and their appendages. Have the perithecia any regular way of opening? Note the length of the appendages as compared with the diameter of the perithecia; also note the form of the tips and of the base, the color and any variation of color in different parts of the appendages. Keep the left hand on the focusing screw, and with the needle in the right hand press with gentle but varying stress upon the cover-glass to rupture the perithecia. Even with great care broken cover-glasses may result, but this pressure should force out the contents of the perithecia. Another method is to remove the slide from the microscope and, with a pencil rubber applied to the cover-glass, rupture the perithecia by gentle grinding between the cover and slide. Note the number and form of the spore-sacs (*asci*) expelled from each of several perithecia. Examine under a power of about 200 diameters and count the number of spores in the asci. Gentle pressure may make them more distinctly visible. Make drawings to illustrate the structural characters observed.

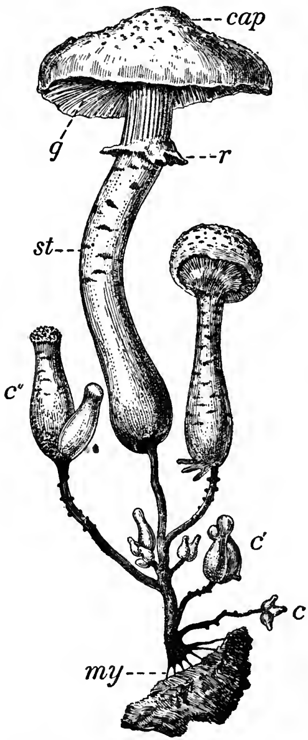


FIG. 194. — A Mushroom (*Agaricus melleus*).
my, mycelium; *c*, *c′*, *c″*, young "buttons"; *st*, stipe or stalk; *r*, ring; *g*, gills.

THE STUDY OF AGARICUS

316. Occurrence. — The common mushroom, *Agaricus campestris*, grows in open fields and pastures in the United States and Europe. It is the mushroom most extensively cultivated for market, and if not found in the field it may be raised from "spawn" (*mycelium*), put up in the shape of bricks, and sold by seedsmen in the large cities. Those who make a specialty of selling it furnish directions for culture free. A moderately warm cellar or basement makes an excellent winter garden for mushrooms.

317. Structure of Mycelium. — Examine some of the spawn, or mycelium, with the magnifying glass and the low power of the microscope, and with a power of 200 diameters or more examine the individual hyphæ which compose it. Are the hyphæ united in cord-like strands or otherwise, or are they entirely separate? Look for cross-partitions in the hyphæ. Is there any peculiar structure to be found at these places? Are the cross-partitions near together or widely separated?

318. The Spore-Plant. — Search for indications of fruiting, and note the appearance of the "button mushrooms" in all available stages. Draw. See if at any stage up to maturity an outer envelope of tissue (*volva*) can be found enclosing the entire fruiting body. If such be present, what becomes of it at maturity? If material is available, compare the species of *Amanita* (poisonous) in regard to this.

Examine specimens in which the cap is expanding and see if there is another tissue forming a *veil* covering the under surface of the cap. If such be present, how is it attached and what becomes of it?

Take a fresh, well-expanded mushroom or toadstool. Remove the stalk, or *stipe*, close under the cap, or *pileus*, and lay the latter, gills down, on a piece of paper. Let it remain undisturbed for a few hours, or over night, so that the spores may fall upon the paper. Note carefully their color, also the form in which they are arranged on the paper. What determines this form? Examine some of the spores under the highest available power of the microscope. Measure and draw.

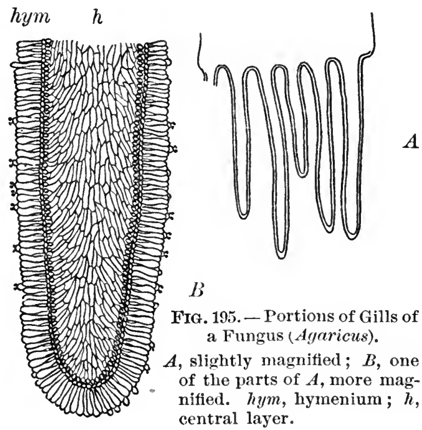


FIG. 195. — Portions of Gills of a Fungus (*Agaricus*). *A*, slightly magnified; *B*, one of the parts of *A*, more magnified. *hym*, hymenium; *h*, central layer.

Describe the stipe. Is it a hollow tube or solid? Does it taper? Note length, diameter, color.

Describe the cap, or pileus, in regard to diameter, thickness, nature and color of the upper surface, also color below.

Examine the plates, or *gills*, which compose the under portion of the pileus. Cut a complete pileus and stipe, through the center, and draw an outline to show the shape, noting particularly how the gills are attached. What is the color of the gills?

319. Origin of Spores. — Make a cross-section of one of the gills, and with a magnifying power of about 200 diameters examine the fruiting cells (*basidia*) which project at right angles to the gill and bear the spores. At how many points (*sterigmata*) on each basidium are spores attached? Draw a basidium, preferably one from which the spores have not yet fallen.

THE STUDY OF YEAST (SACCHAROMYCES CEREVISIÆ)

320. Growth of Yeast in Dilute Syrup. — Mix about an eighth of a cake of compressed yeast with about a teaspoonful of water and stir until a smooth, thin mixture is formed. Add this to about half a pint of water in which a tablespoonful of molasses has been dissolved. Place this mixture in a wide-mouthed bottle which holds one or one and a half pints, stopper *very loosely*[1] and set aside for from twelve to twenty-four hours in a place in which the temperature will be from 70 to 90 degrees. Watch the liquid meantime and note:

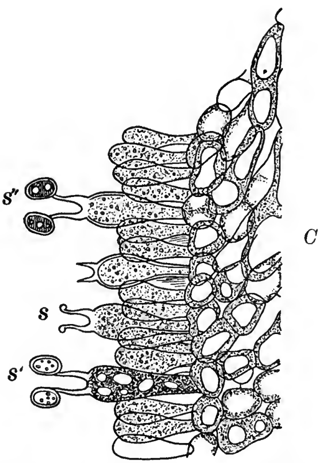


FIG. 196. — Part of the Preceding Figure. (× about 300.)

C, layer of cells immediately under the hymenium; *s*, *s′*, *s″*, three successive stages in growth of spores.

(*a*) The rise of bubbles of gas in the liquid.

(*b*) The increasing muddiness of the liquid, a considerable sediment usually collecting at the end of the time mentioned.

(*c*) The effect of cooling off the contents of the bottle by immersing it in broken ice if convenient, or, if this is not practicable, by standing it for half an hour in a pail of the coldest water obtainable, or leaving it for an hour in a refrigerator, afterwards warming the liquid again.

(*d*) The effect of shutting out light from the contents of the bottle by covering it with a tight box or large tin can.

[1] If the cork is crowded into the neck with any considerable force, pressure of gas and an explosion may result.

(*e*) The result of filling a test-tube or a very small bottle with some of the syrup-and-yeast mixture, from which gas-bubbles are freely rising, and immersing the small bottle up to the top of the neck for fifteen minutes in boiling water. Allow this bottle to stand in a warm place for some hours after the exposure to hot water. What has happened to the yeast-plants?

(*f*) The behavior of a lighted match lowered into the air space above the liquid in the large bottle, after the latter has been standing undisturbed in a warm place for an hour or more.

(*g*) The smell of the liquid and its taste.

321. Microscopical Examination of the Sediment.[1] — Using a very slender glass tube as a pipette, take up a drop or two of the liquid and the upper layer of the sediment and place on a glass slide, cover with a very thin cover-glass and examine with the highest power that the microscope affords.

Note:

(*a*) The general shape of the cells.

(*b*) Their granular contents.

(*c*) The clear spot, or vacuole, seen in many of the cells.

Sketch some of the groups and compare the sketches with Fig. 197.

Run in a little iodine solution under one edge of the cover-glass, at the same time touching a bit of blotting paper to the opposite edge, and notice the color of the stained cells. Do they contain starch?

Place some vigorously growing yeast on a slide under a cover-glass and run in a little eosin solution or magenta solution. Note the proportion of cells which stain at first and the time required for others to stain. Repeat with yeast which has been placed in a slender test-tube and held for two or three minutes in a cup of boiling water.

With a very small cover-glass, not more than three-eighths of an inch in diameter, it may be found possible by laying a few bits of blotting paper or cardboard on the cover-glass and pressing it against the slide to burst some of the stained cells and thus show their thin, colorless *cell-walls* and their semi-fluid contents, *protoplasm*, nearly colorless in its natural condition but now stained by the iodine.

[1] See Huxley and Martin's *Biology*, under *Torula*.

EXPERIMENT XXXIX

Can Yeast grow in Pure Water or in Pure Syrup? — Put a bit of compressed yeast of about the size of a grain of wheat in about four fluid ounces of distilled water, and another bit of about the same size in four fluid ounces of 10 per cent solution of rock candy in distilled water; place both preparations in a warm place, allow to remain for twenty-four hours, and examine for evidence of the growth of the yeast added to each.

322. Size, Form, and Structure of the Yeast-Cell. — The student has discovered by his own observations with the microscope that the yeast-cell is a very minute object, — much smaller than most of the vegetable cells which he has hitherto examined. The average diameter of a yeast-cell is about $\frac{1}{3000}$ of an inch, but they vary greatly both ways from the average size.

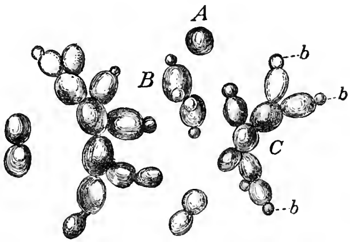


FIG. 197. — Yeast (*Saccharomyces ellipsoideus*) budding actively.

A, a single cell; *B*, group of two budding cells; *C*, a large group; *b*, buds.

The general form of most of the cells of ordinary yeast is somewhat egg-shaped. The structure is extremely simple, consisting of a thin cell-wall, which is wholly destitute of markings, and a more or less granular semi-fluid protoplasm, sometimes containing a portion of clearer liquid, the *vacuole*, well shown in the larger cells of Fig. 197.[1]

323. Substances which compose the Yeast-Cell. — The cell-wall is composed mostly of *cellulose;* the protoplasm consists largely of water, together with considerable portions of a proteid substance,[2]

[1] This is not the ordinary commercial yeast.

[2] It may be found troublesome to apply tests to the yeast-cell on the slide, under the cover-glass. Testing a yeast cake is not of much value, unless it may be assumed that compressed yeast contains little foreign matter and consists mostly of yeast-cells. Still the test is worth making. Millon's reagent does not work well, but the red or maroon color which constitutes a good test for proteids is readily obtained by mixing a teaspoonful of granulated sugar with enough strong sulphuric acid to barely moisten the sugar throughout, and then, as quickly as possible, mixing a bit of yeast cake with the acid and

some fat, and very minute portions of *sulphur*, *phosphorus*, *potash*, *magnesia*, and *lime*. It is destitute of chlorophyll, as would be inferred from its lack of green color, and contains no starch.

324. Food of the Yeast-Cell; Fermentation. — The diluted molasses in which the yeast was grown in Exp. XXXIX contained all the mineral substances mentioned in Sect. 323, together with sugar, proteid materials, and water. The addition of a little nitrate of ammonium would probably have aided the growth of the yeast in this experiment, by supplying more abundantly the elements out of which the yeast constructs its proteid cell-contents. A great deal of sugar disappears during the growth of the yeast.[1] Most of the sugar destroyed is changed into carbon dioxide (which the student saw rising through the liquid in bubbles) and alcohol, which can be separated from the liquid by simple means. The process of breaking up weak syrup into carbon dioxide and alcohol by aid of yeast is one kind of *fermentation;* it is of great practical importance in bread-making and in the manufacture of alcohol. Since grape juice, sweet cider, molasses and water, and similar liquids, when merely exposed to the air soon begin to ferment and are then found to contain growing yeast, it is concluded that dried yeast-cells, in the form of dust, must be everywhere present in ordinary air.

325. Yeast a Plant; a Saprophyte. — The yeast-cell is known to be a plant, and not an animal, from the fact of its producing a coating of cellulose around its protoplasmic contents and from the fact that it can produce proteids out of substances from which animals could not produce them.[2]

On the other hand, yeast cannot live wholly on carbon dioxide, nitrates, water, and other mineral substances, as ordinary green plants can. It gives off no oxygen, but only carbonic acid gas, and is therefore to be classed with the *saprophytes*, like the Indian pipe, among flowering plants (Sect. 180).

sugar. A comparative experiment may be made at the same time with some other familiar proteid substance, *e.g.*, wheat-germ meal.

[1] The sugar contained in molasses is partly cane sugar and partly grape sugar. Only the latter is detected by the addition of Fehling's solution. Both kinds are destroyed during the process of fermentation.

[2] For example, tartrate of ammonia.

326. Multiplication of Yeast. — It is worth while to notice the fact that yeast is one of the few cryptogams which have for ages been largely cultivated for economic purposes. Very recently yeast producing has become a definite art, and the cakes of compressed yeast so commonly sold afford only one instance of the success that has been attained in this process. While yeast-cells are under favorable conditions for growth, they multiply with very great rapidity. Little protrusions are formed at some portion of the cell-wall, as the thumb of a mitten might be formed by a gradual outgrowth from the main portion. Soon a partition of cellulose is constructed, which shuts off the newly formed outgrowth, making it into a separate cell, and this in turn may give rise to others, while meantime the original cell may have thrown out other offshoots. The whole process is called *reproduction by budding.* It is often possible to trace at a glance the history of a group of cells, the oldest and largest cell being somewhere near the middle of the group and the youngest and smallest members being situated around the outside. Less frequently the mode of reproduction is by means of *spores*, new cells (usually four in number), formed inside one of the older cells (*ascus*). At length the old cell-wall bursts, and the spores are set free, to begin an independent existence of their own.

In examining the yeast-cell the student has been making the acquaintance of plant life reduced almost to its lowest terms. The very simplest plants consist, like the slime moulds, of a speck of jelly-like protoplasm. Yeast is more complex, from the fact that its protoplasm is surrounded by an envelope of cellulose, the cell-wall.

THE STUDY OF PHYSCIA

327. Occurrence. — *Physcia* is one of the commonest lichens. It grows attached to the bark of various trees.

328. The Thallus. — *Physcia* consists chiefly of an irregularly expanded growth somewhat leaf-like in texture. It is best to be wet for study. Is it separable from the bark to which it is attached or is it combined with it (incrusted)? Describe the general outline of the margin, the general color, and any special variations of color above, also below. How is the thallus attached to the bark?

329. The Fruit. — Look for small lance-shaped disks seated upon the thallus. Note the approximate sizes and color within and without. These disks are called *apothecia*. Note the very minute black specks (*spermogones*) which are scattered in the surface of the thallus. Pick one from the thallus, with as little of the thallus as possible, and examine under high power. It may be macerated in a drop of potash solution and crushed under the cover-glass. If the contents are not easily defined, they may then be made more opaque by a drop of acetic acid or a stain. The minute colorless bodies contained in the spermogones are

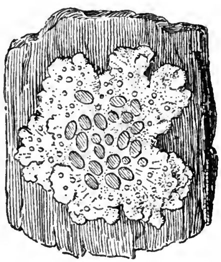


FIG. 198. — A Lichen (*Xanthoria*). (Natural size.)

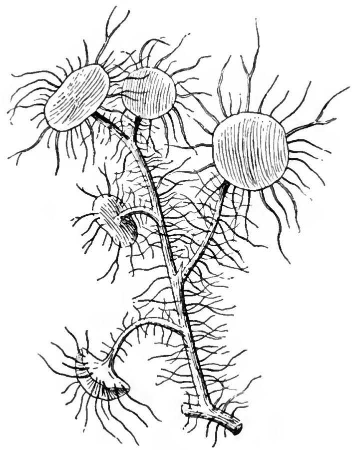


FIG. 199. — A Lichen (*Usnea*). (Natural size.)

called *spermatia*. Their office in *Physcia* is obscure, but in a few lichens they are thought to unite with a trichogyne cell, as in the red algæ.[1] Note the minute, powdery masses (*soredia*) on the surface of the thallus. Macerate if necessary under the cover-glass and examine under a high power. Compare with the structure of the thallus as seen in cross-section. (See next paragraph.) These soredia easily become detached and develop into new plants.

Prepare for sectioning by imbedding a small portion of the thallus with an apothecium in a piece of pith or by any suitable device for sectioning, and cut thin sections of thallus and fruit.

[1] This, however, is doubtful. See Strasburger, Noll, Schenk, and Schimper's *Text-Book of Botany*, p. 380.

330. Examination of the Thallus. — The thallus of *Physcia* as seen in cross-section will be found to consist of four layers, the upper cortical, gonidial, medullary, and the lower cortical. The cortical layers will be seen to serve for protection, answering the purpose of an epidermis or bark. The cells which compose them make what is called a *false parenchyma,* — resembling parenchyma in form but as to origin being transformed fungal hyphæ. Note the form of the hyphæ composing the medullary layer. Are there any cross-partitions? Do any cells appear circular, and if so, what is the explanation? The upper portion of the cortical layer, having green cells intermixed, constitutes the gonidial layer. Why should the green cells be at the upper part of the medullary layer? Can you detect any connection between the green cells and the hyphæ? Do these green cells resemble any cells previously studied?

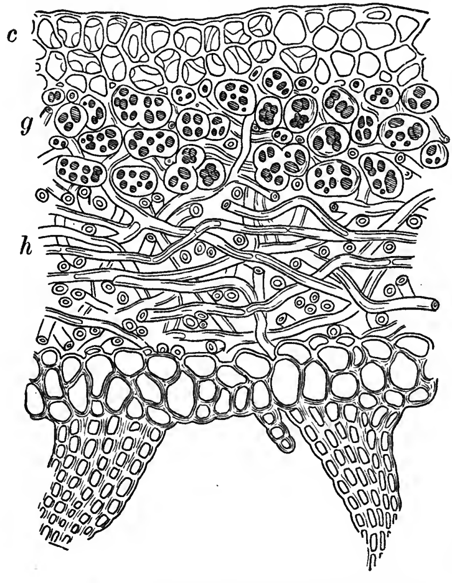


FIG. 200. — Transverse Section through Thallus of a Lichen (*Sticta fuliginosa*). (× 500.)
c, cortical or epidermal layer ; *g*, gonidia ; *h*, hyphæ.

Make a diagram to show the structure of the thallus.

What arrangement of layers would you expect to find in a lichen thallus, upright or suspended? Compare the arrangement in the fruit-body (*apothecium*), describe, and sketch. How does the layer of cells beneath the spore-sacs resemble the cortical layer? All but these two layers may be considered as part of the thallus. To make out the details of the fruit, the section must be very thin.

Examine the spore-sacs (*asci*) and look for spores in different stages of formation. How many spores are found in each ascus? What other bodies occur among the asci? Draw these, also asci and spores.

331. Lichens. — Lichens were formerly supposed to be a distinct class of plants, and it is only about thirty years since their real nature began to be understood. A lichen is now known to be a combination of two plants. The green cells, called the *gonidia*, belong to some species of alga, and the remainder, the larger portion of the growth, is a fungus parasitic upon that alga. The groups of lichens correspond in structure to certain groups of fungi, but the genera are sufficiently distinct so that lichens are best considered by themselves for purposes of study and classification.

The relation of the fungus and its algal host is not that of destructive parasitism, but rather a mutual relation (*symbiosis*) in which both fungus and alga may have a vigorous growth. The relationship has been investigated in various ways, and it has been found that, while the alga may grow independent of the fungus, the germinating fungus spores can grow only to a limited extent if deprived of the algal host; but if supplied naturally or artificially with the proper alga they make a normal growth.

The same alga may serve as gonidia to a number of lichens, often of very different form, and while the number of lichens reaches into the thousands, the number of algæ known to serve as gonidia is quite small.

Lichens are widely distributed in all zones but flourish particularly in northern regions where other vegetation is scanty. Some were formerly important as sources of dyes. "Iceland moss" is a lichen used for food, and a finely branching form, growing in extensive mats on the soil, serves as food for the reindeer and is known as "reindeer moss."

Most lichens grow on the bark of trees, on rocks, or soil where they have little moisture except during rainfall, but some grow where they are constantly wet. Some of the latter are gelatinous. Most of the conspicuous lichens are foliaceous or else have a thallus composed of branching, cylindrical, thread-like portions. But many species, often less conspicuous, are crustaceous, growing as if they formed part of the bark or rock to which they are attached.

332. Fungi. — The yeasts, moulds, rusts, mildews, and mushrooms represent an immense group of plants of which about forty-five thousand species are now known in the world. They range from the very simple to quite complex forms, growing as saprophytes or parasites under a great variety of conditions. Their structure and life history are so varied as to constitute a long series of divisions and subdivisions.[1] Chlorophyll is absent from fungi, and they are destitute of starch, but produce a kind of cellulose which appears to differ chemically from that of other plants. Unable to build up their tissues from carbonic acid gas, water, and other mineral matters, they are to be classed, with animals, as consumers rather than as producers, acting on the whole to diminish rather than to increase the total amount of organic material on the earth.

[1] See Strasburger, Noll, Schenk, and Schimper's *Text-Book of Botany*, pp. 340–381 incl., also Potter and Warming's *Systematic Botany*, p. 1, and Engler's *Syllabus der Pflanzenfamilien*, Berlin, 1898, pp. 25–47.

333. Occurrence and Mode of Life of Fungi. — Among the most important cryptogamous plants are those which, like the bacteria of consumption, of diphtheria, of typhoid fever, or of cholera, produce disease in man or in the lower animals. The subclass which includes these plants is known by the name *Bacteria.* Bacteria are now classed by some as a separate group, lower than fungi. Some of the most notable characteristics of these plants are their extreme minuteness and their extraordinary power of multiplication. Many bacteria are on the whole highly useful to man, as is the case with those which produce decay in the tissues of dead plants or animals, since these substances would, if it were not for the destructive action of the bacteria of putrefaction and fermentation, remain indefinitely after death to cumber the earth and lock up proteid and other food needed by new organisms.

The mushrooms and their allies include about one-fourth of the fungi. Some, such as the "dry-rot" fungus, mistakenly so called, cause great destruction to living and dead tree trunks and timber in economic use. The common mushroom, *Agaricus campestris*, is the most important edible species. Probably five hundred kinds can be eaten, but only a few are good food, and even these contain but little nutriment. Some species are dangerous, and a few are deadly poisons. The puffballs are a small group allied to the mushrooms. Most of them are edible and of good quality.

The mildews (*Microsphæra*, etc.) and the "black-knot" of the plum trees are of a group which likewise includes about one-fourth of the fungi. A considerable number are parasites, injurious to vegetation, while thousands of others grow on dead leaves, twigs, etc.

The "rust" of wheat and the "smut" of corn represent groups numbering only a few hundreds of species, which are very important because they are all parasites on living plants, many on our most important economic plants.

Fig. 191, representing another small group of destructive parasites, shows clearly how a parasitic fungus grows from a spore which has found lodgment in the tissues of a leaf and pushes out stalks through the stomata to distribute its spores.

CHAPTER XXI

TYPES OF CRYPTOGAMS; BRYOPHYTES

334. The Group Bryophytes. — Under this head are classed the liverworts and the mosses. Both of these classes consist of plants a good deal more highly organized than the thallophytes. Bryophytes have no true roots, but they have organs which perform the work of roots. Some of them have leaves (Fig. 206), while others have none (Fig. 201). Fibro-vascular bundles are wanting. The physiological division of labor is carried pretty far among all the bryophytes. They have special apparatus for absorbing water and sometimes for conducting it through the stem; stomata are often present and sometimes highly developed. There are chlorophyll bodies, often arranged in cells extremely well situated for acting

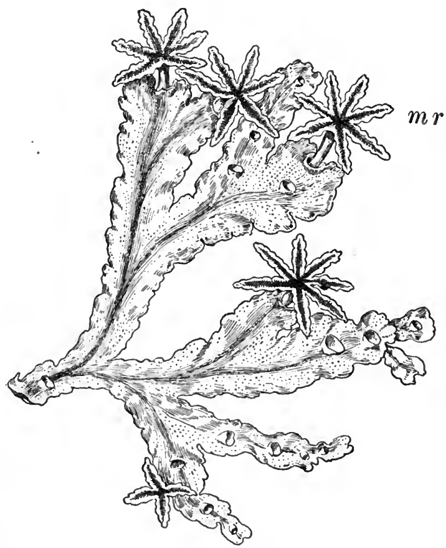


FIG. 201. — Part of Male Thallus of a Liverwort (*Marchantia disjuncta*). (Enlarged.) *mr*, male receptacle.

on the carbon dioxide gas which the plant absorbs, that is, arranged about rather large air chambers.

Reproduction is of two kinds, sexual and asexual, and the organs by which it is carried on are complicated and highly organized. An *alternation of generations* occurs, that is, the life history of any species embraces two forms: a *sexual generation*, which produces two kinds of cells that by their union give rise to a new plant; the *asexual generation*, which multiplies freely by means of special cells known as *spores*.

FIG. 202. — Part of Female Thallus of *M. disjuncta*. (Enlarged.)
fr, female receptacle; *c*, cups with gemmæ.

THE STUDY OF MARCHANTIA

335. Occurrence. — *Marchantia* grows on soil or rocks in damp shaded places and is widely distributed.

336. The Thallus. — In general form the thallus bears some resemblance to that of some of the lichens, as *Parmelia*, but is plainly different in color, mode of branching, and internal structure under the microscope. Under the microscope (see below) the individual cells may be compared with those of the medullary layer in *Physcia*.

Note the color and general shape of the thallus and study carefully the mode of branching. The origin of the growing cells is at the tip, but cells so originating afterward multiply more rapidly, so that the tip comes to be in a notch.

Viewing the thallus as an opaque object, note the diamond-shaped network on the upper surface and the dot-like circle in the middle of each diamond.

Examine the under surface for (1) rhizoids and (2) scales.

337. Internal Structure. — Cut thin cross-sections of the thallus in the same way as for *Physcia*, making some pass through the circular dots mentioned above. Examine under a high power and note the different kinds and layers of cells composing the thallus. Note the character of the cells forming the upper and lower surfaces. Describe the cells which are next above those of the lower epidermis, their shape, color of contents, approximate number of horizontal rows. Have they any evident intercellular spaces? Find cells connecting these with the upper epidermis and constituting the network of lines seen on the surface of the thallus. Note the air cavity bounded by these lines and the loose cells which occupy it in part. What is the color of their contents? How are they attached, and how arranged? Can you discover any opening through the epidermis? If so, describe it.

FIG. 203. — Section through Antheridial Receptacle of *Marchantia*. (Magnified.)

a, antheridium.

Make drawings to illustrate the details of structure observed.

338. Gemmæ. — Look for a thallus bearing little green cups formed of its own substance. Describe the contents of the cup. The bodies are called *gemmæ*. They originate by vegetative growth alone and when detached may grow into new plants.

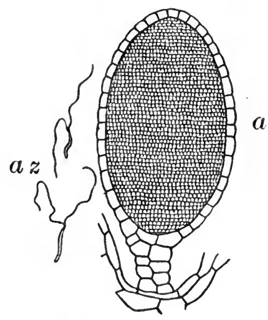


FIG. 204. — Sectional View of an Antheridium of *Marchantia*.

a, antheridium; *az*, antherozoids, × 700.

339. Fruiting Organs. — Look for thalli bearing stalks with umbrella-like expansions. The umbrellas are of two kinds, one disk-like with crenate points (how many?) and the other has rays (how many?) elongated and curving downward. Is there any difference in the height of the two kinds?

Do both occur on the same thallus? On what part of the thallus do they occur, and do they differ in this respect?

340. Antheridia. — The antheridia are formed as outgrowths from the upper surface of the crenate receptacle, but by further growth of the receptacle they become imbedded. They should be examined under a high power and sketched in outline. The antheridium produces numerous motile antherozoids, each with two cilia.

341. Archegonia and Sporophytes. — The receptacle with recurved rays bears the archegonia. Note whether they occur above or below and in what relation to the rays. How are the archegonia protected? Note the cells which surround the central canal and form the elongated neck of the archegonium. Does the archegonium open upward or downward? At the base look for the germ-cell.

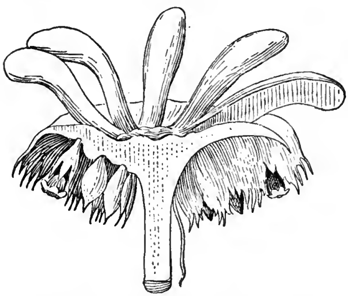


Fig. 205. — Sectional View of Female Receptacle of *Marchantia*. (× 5.)

The antherozoids enter the central canal and penetrating to the egg-cell fertilize it, after which it begins to divide and grows into a sporophyte. In the older specimens, therefore, the sporophytes will be found more or less developed. The archegonium remains upon the tip of the sporophytes. The mature sporophyte contains the spores and also peculiar elongated tapering threads with spiral thickenings. These are called *elaters*.

342. Hepaticæ. — *Marchantia* represents only a small division of the *Hepaticæ*, and is not typical of the larger number of species. In spite of this it is chosen for study, because it is widely distributed and more available for study than most others. In most species the fruit lasts but a little while and good material is hard to obtain. In Marchantia the fruiting organs are abundant, more gradual in their development, and more persistent. Marchantia and its allies consist chiefly of the thallus in the vegetative condition, while the greater number of Hepaticæ have a stem and leaves. Thus they approach closely to the mosses. But mosses usually have leaves on all sides of the stem, while the leaves of Hepaticæ are two-ranked, spreading laterally, with sometimes a third row of leaves or scales underneath. The leaves of mosses usually have more than one layer of cells in some part, but the leaves of the leafy Hepaticæ have but one layer of cells throughout. The forms of the leaves are often very curious and interesting. The sporophyte of most mosses consists of a capsule with a lid, while in the leafy Hepaticæ the capsule usually opens by splitting longitudinally into two to four valves.

Different species of Hepaticæ grow on damp soil, rocks, and the bark of trees. Many are capable of enduring drought and reviving with moisture.

THE STUDY OF PIGEON-WHEAT MOSS (*POLYTRICHUM COMMUNE*)

343. Occurrence. — This moss is widely distributed over the surface of the earth, and some of its relatives are among the best known mosses of the northern United States. Here it grows commonly in dry pastures or on hillsides, not usually in densely shaded situations.

344. Form, Size, and General Characters. — Study several specimens which have been pulled up with root-hairs. Note the size, general form, color, and texture of all the parts of the plants examined. Some of them probably bear *spore-capsules* or *sporophytes* like those shown in Fig. 206, while others are without them. Sketch one plant of each kind, about natural size.

What difference is noticeable between the appearance of the leaves in those plants which have spore-capsules and those which have none? Why is this?

In some specimens the stem may be found, at a height of an inch or more above the roots, to bear a conical, basket-shaped enlargement,

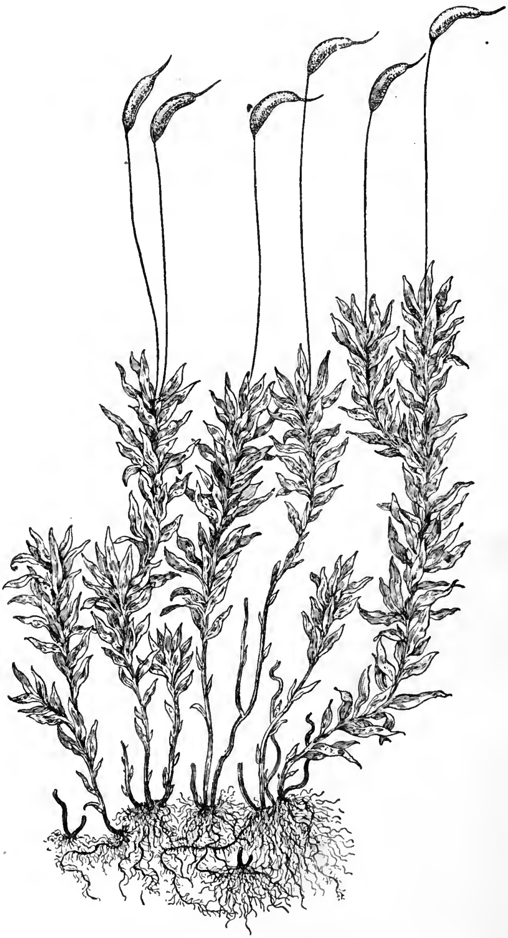


FIG. 206. — A Moss, *Catharinea*.

The sporophytes of this moss are usually rather more slender than as here represented.

out of the center of which a younger portion of the stem seems to proceed; and this younger portion may in turn end in a similar enlargement, from which a still younger part proceeds.

Note the difference in general appearance between the leaves of those plants which have just been removed from the moist collecting-box and those which have been lying for half an hour on the table. Study the leaves in both cases with the magnifying glass in order to find out what has happened to them. Of what use to the plant is this change? Put some of the partially dried leaves in water, in a

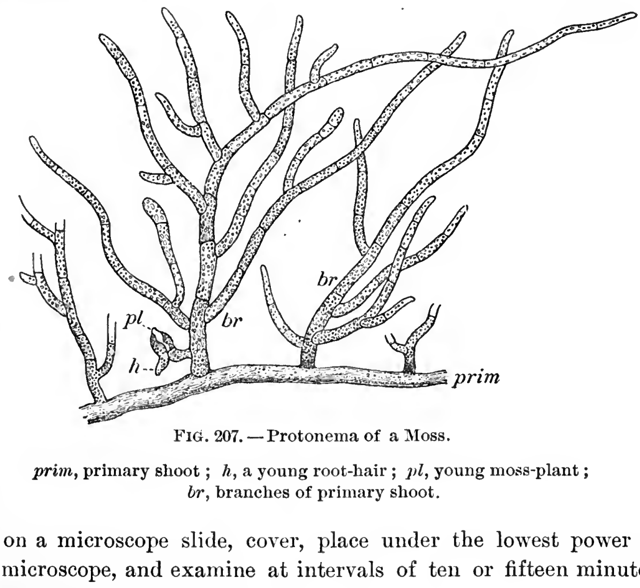


FIG. 207.—Protonema of a Moss.

prim, primary shoot; *h*, a young root-hair; *pl*, young moss-plant; *br*, branches of primary shoot.

cell on a microscope slide, cover, place under the lowest power of the microscope, and examine at intervals of ten or fifteen minutes. Finally sketch a single leaf.

345. Minute Structure of the Leaf and Stem. — The cellular structure of the pigeon-wheat moss is not nearly as simple and convenient for microscopical study as is that of the smaller mosses, many of which have leaves composed, over a large part of their surfaces, of but a single layer of cells, as shown in Fig. 209. If any detailed study of the structure of a moss is to be made, it will, therefore, be better for the student to provide himself with specimens of almost any of the smaller genera,[1] and work out what he can in regard to their minute anatomy.

FIG. 208.—The Antheridium of a Moss (*Funaria*) and its Contents.

a, antheridium; *b*, escaping antherozoids, × 350; *c*, a single antherozoid of another moss, × 800.

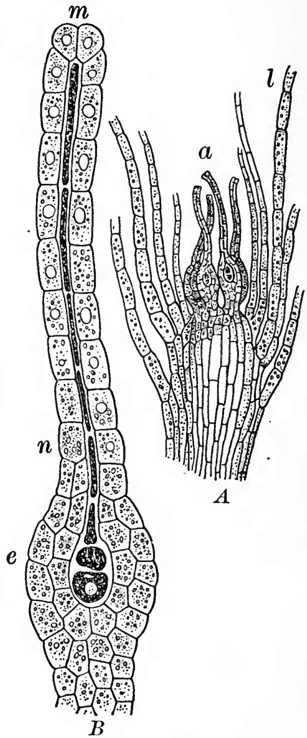


FIG. 209.—Portions of Fertile Plant of a Moss (*Funaria*).

A, longitudinal section of summit of plant, × 100; *a*, archegonia; *l*, leaves; *B*, an archegonium, × 550; *e*, enlarged ventral portion with central cell; *n*, neck; *m*, mouth.

346. Sporophytes.—That part of the reproductive apparatus of a common moss which is most apparent at a glance is the *sporophyte* or *spore-capsule* (Fig. 206). This is covered, until it reaches maturity, with a hood which is easily detached. Remove the hood from one

[1] As *Mnium* or *Bryum*.

of the capsules, examine with a magnifying glass, and sketch it. Note the character of the material of which its outer layer is composed.

Sketch the uncovered capsule as seen through the magnifying glass, noting the little knob at its base and the circular lid.

Pry off this lid, remove some of the mass of spores from the interior of the capsule, observe their color as seen in bulk through the magnifying glass, then mount in water, examine with the highest obtainable power of the microscope, and sketch them. These spores, if sown on moist earth, will each develop into a slender, branched organism, consisting, like pond-scum, of single rows of cells (Fig. 207) called the *protonema.*

347. Other Reproductive Apparatus. — The student cannot, without spending a good deal of time and making himself expert in the examination of mosses, trace out for himself the whole story of the reproduction of any moss. It is sufficient here to give an outline of the process. The protonema develops buds, one of which is shown in Fig. 207, and the bud grows into an ordinary moss plant. This plant, in the case of the pigeon-wheat moss, bears organs of a somewhat flower-like nature, which contain either *antheridia* (Fig. 208), organs which produce fertilizing cells called *antherozoids*, or *archegonia* (Fig. 209), organs which produce egg-cells, but in this moss antheridia and archegonia are not produced in the same "moss-flower." The plants therefore correspond to diœcious ones among flowering plants.

After the fertilization of the egg-cell, by the penetration of antherozoids to the bottom of the flask-shaped archegonium, the development of the egg-cell into *sporophyte* begins; the latter rises as a slender stalk, while the upper part of the archegonium is carried with it and persists for a time as the hood or *calyptra.*

CHAPTER XXII

TYPES OF CRYPTOGAMS; PTERIDOPHYTES

348. The Group Pteridophytes. — Under this head are classed the ferns, the scouring-rushes, and the club-mosses. They are the most highly organized of cryptogams, having true roots, and often well-developed stems and leaves.

THE STUDY OF A FERN[1]

349. Conditions of Growth. — If the specimens studied were collected by the class, the collectors should report exactly in regard to the soil and exposure in which the plants were found growing. Do any ferns occur in surroundings decidedly different from these? What kind of treatment do ferns need in house culture?

350. The Underground Portion. — Dig up the entire underground portion of a plant of ladyfern. Note the color, size, shape, and appendages of the rootstock. If any are at hand which were collected in their late winter or early spring condition, examine into the way in which the leafy parts of the coming season originate from the rootstock, and note their peculiar shape (Fig. 210, *A*). This kind of vernation (Sect. 136) is decidedly characteristic of ferns. Observe the number and distribution of the roots along the rootstock. Bring out all these points in a sketch.

[1] The outline here given applies exactly only to *Asplenium filix-fœmina*. Any species of *Asplenium* or of *Aspidium* is just as well adapted for study. *Cystopteris* is excellent, but the indusium is hard to find. *Polypodium vulgare* is a simple and generally accessible form, but has no indusium. *Pteris aquilina* is of world-wide distribution, but differs in habit from most of our ferns. The teacher who wishes to go into detail in regard to the gross anatomy or the histology of ferns as exemplified in *Pteris* will find a careful study of it in Huxley and Martin's *Biology*, or a fully illustrated account in Sedgwick and Wilson's *Biology*.

351. The Frond. — Fern leaves are technically known as *fronds*. Observe how these arise directly from the rootstock.

Make a somewhat reduced drawing of the entire frond, which consists of a slender axis, the *rhachis*, along which are distributed many leaflets or *pinnæ*, each composed of many *pinnules*. Draw the under side of one of the pinnæ, from near the middle of the frond, enlarged to two or three times its natural size, as seen through the magnifying glass. Note just how each pinnule is attached to its secondary rhachis.

Examine the under side of one of the pinnules (viewed as an opaque object without cover-glass) with the lowest power of the microscope, and note:

(*a*) The "fruit-dots" or *sori* (Fig. 210, *B*) (already seen with the magnifying glass, but now much more clearly shown).

(*b*) The membranous covering or *indusium* of each sorus (Fig. 210, *C*). Observe how this is attached to the veins of the pinnule. In such ferns as the common brake (*Pteris*) and the maidenhair (*Adiantum*) there is no separate indusium, but the *sporangia* are covered by the incurved edges of the fronds.

(*c*) The coiled spore-cases or sporangia, lying partly covered by the indusium. How do these sporangia discharge their spores?

Make a drawing, or several drawings, to bring out all these points.

Examine some of the sporangia, dry, with a power of about fifty or seventy-five diameters, and sketch. Scrape off a few sporangia, thus disengaging some spores, mount the latter in water, examine with a power of about 200 diameters, and draw.

352. Life History of the Fern. — When a fern-spore is sown on damp earth it gradually develops into a minute, flattish object, called a *prothallium* (Fig. 211). It is a rather tedious process to grow prothallia from spores, and the easiest way to get them for study is to look for them on the earth or on the damp outer surface of the flower-pots in which ferns are growing in a greenhouse. All stages of germination may readily be found in such localities.

Any prothallia thus obtained for study may be freed from particles of earth by being washed, while held in very small forceps, in a gentle stream of water from a wash-bottle. The student should then mount the prothallium, bottom up, in water in a shallow cell,

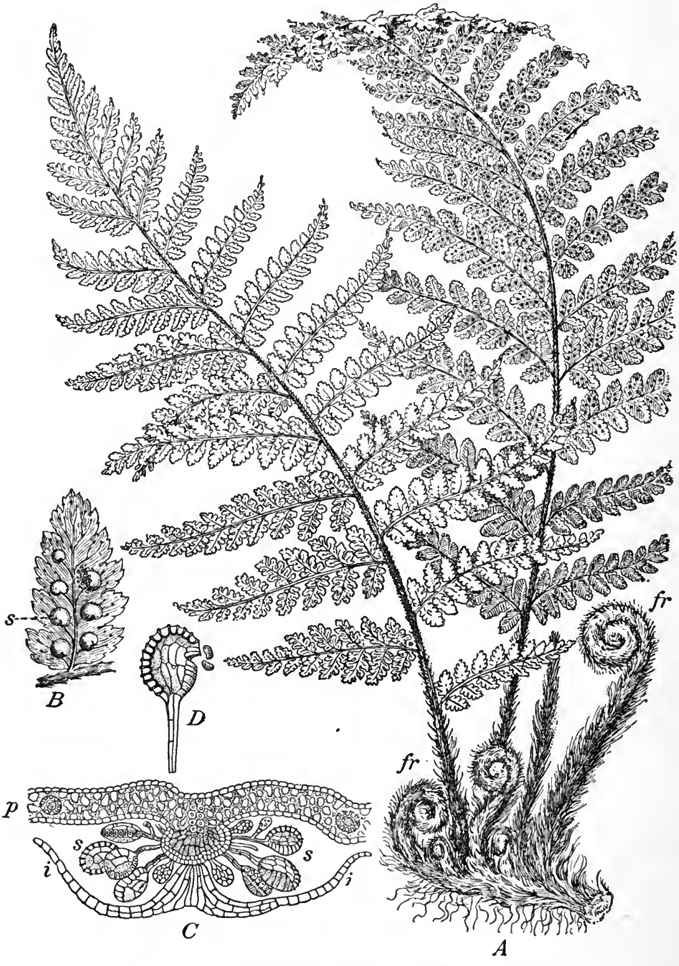


FIG. 210. — Spore-Plant of a Fern (*Aspidium Filix-mas*).

A, part of rootstock and fronds, not quite one-sixth natural size; *fr*, young fronds unrolling; *B*, under side of a pinnule, showing sori, *s*; *C*, section through a sorus at right angles to surface of leaf, showing indusium, *i*, and sporangia, *s*; *D*, a sporangium discharging spores. (*B* is not far from natural size. *C* and *D* are considerably magnified.)

cover with a large cover-glass, and examine with the lowest power of the microscope. Note:

(*a*) The abundant root-hairs, springing from the lower surface of the prothallium.

(*b*) The variable thickness of the prothallium, near the edge, consisting of only one layer of cells.

(*c*) (In some mature specimens) the young fern growing from the prothallium, as shown in Fig. 211, *B*.

The student can hardly make out for himself, without much expenditure of time, the structure of the *antheridia* and the *archegonia* (Fig. 211, *A*), by the coöperation of which fertilization takes place on much the same plan as that already described in the case of mosses. The fertilized egg-cell of the archegonium gives rise to the young fern, the *sporophyte* which grows at first at the expense of the parent prothallium but soon develops roots of its own and leads an independent existence.

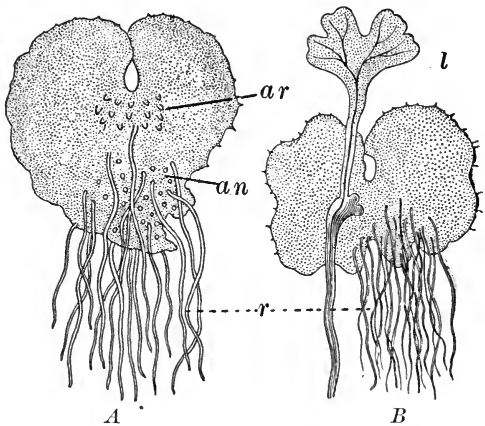


FIG. 211. — Two Prothallia of a Fern (*Aspidium*).
A, under surface of a young prothallium; *ar*, archegonia; *an*, antheridia; *r*, rhizoids; *B*, an older prothallium with a young fern-plant growing from it; *l*, leaf of young fern. (Both × about 8.)

353. Nutrition. — The mature fern makes its living, as flowering plants do, by absorption of nutritive matter from the soil and from the air, and its abundant chlorophyll makes it easy for the plant to decompose the supplies of carbon dioxide which it takes in through its stomata.

FERNS

354. Structure, Form, and Habits of Ferns.— The structure of ferns is much more complex than that of any of the groups of cryptogamous plants discussed in the earlier portions of the present chapter. They are possessed of well-defined fibro-vascular bundles, they form a variety of parenchymatous cells, the leaves have a distinct epidermis and are provided with stomata

Great differences in size, form, and habit of growth are found among the various genera of ferns. The tree ferns of South America and of many of the islands of the Pacific Ocean sometimes rise to a height of forty feet, while the most minute species of temperate and colder climates are not as large as the largest mosses. Some species climb freely, but most kinds are non-climbing plants of moderate size, with well-developed rootstocks, which are often, as in the case of the bracken-fern, or brake,[1] and in *Osmunda*, very large in proportion to the parts of the plant visible above ground.

355. Economic Value of Ferns. — Ferns of living species have little economic value, but are of great interest, even to non-botanical people, from the beauty of their foliage.

During that vast portion of early time known to geologists as the Carboniferous Age, the earth's surface in many parts must have been clothed with a growth of ferns more dense than is now anywhere found. These ferns, with other flowerless herbs and tree-like plants, produced the vegetable matter out of which all the principal coal beds of the earth have been formed.

[1] *Pteris aquilina.*

356. Reproduction in Ferns.—The reproduction of ferns is a more interesting illustration of alternation of generations than is afforded by mosses. The sexual plant, *gametophyte*, is the minute prothallium, and the non-sexual plant, *sporophyte*, which we commonly call the fern, is merely an outgrowth from the fertilized egg-cell, and physiologically no more important than the sporophyte of a moss, except that it supplies its own food instead of living parasitically. Like this sporophyte, the fern is an organism for the production of vegetative spores, from which new plants endowed with reproductive apparatus may grow.

THE STUDY OF A CLUB-MOSS (*LYCOPODIUM*)

357. Occurrence. — Several species of *Lycopodium* are common in rich woods in the northern and mountainous portions of the eastern United States. Any species may be studied.

358. Examination. — Note whether the plant is chiefly erect or prostrate and vine-like. Describe the mode of branching. Are the leaves arranged flat-wise or equally on all sides of the stem? Describe the leaves briefly. Are they all of one kind or do some portions of the plant evidently have smaller leaves?

Select fruiting specimens and determine the position of the sporangia. Is the leaf, near whose base each sporangium is situated, like the ordinary foliage leaves of the plant? Are the fruiting portions of the plant similar in general aspect or different from the rest of the plant and raised above it on stalks? Examine the spores. Are they all of one kind?

If *Selaginella* is used in place of *Lycopodium* or for comparison, two kinds of sporangia are to be sought, differing chiefly in shape. Describe each briefly. Compare the number of spores in each. The larger spores (*macrospores*) germinate and at length produce prothallia bearing archegonia, while the smaller produce prothallia bearing antheridia. The archegonia, after fertilization, develop each an embryo. This grows, remaining for a time attached to the macrospore, and at length forms a new spore-plant.

THE STUDY OF A SCOURING-RUSH (*EQUISETUM*)

359. Occurrence. — The common horse-tail, *Equisetum arvense*, is widely distributed in the United States, east, west, north, and south. It is very often found on sand hills and along railroad embankments.

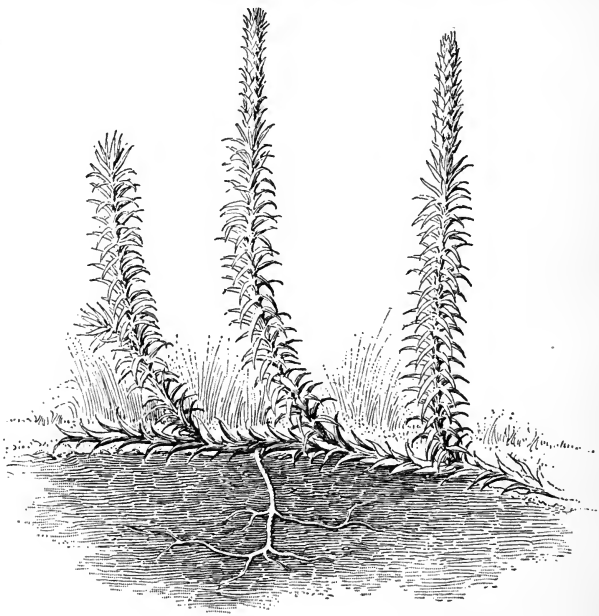


FIG. 212. — Plant of Lycopodium (*L. annotinum*).

The fruiting stems appear very early in the spring and are of short duration. The sterile vegetative growth follows, becoming well grown in June.

360. Examination of Rootstocks and Roots. — Examine the underground portions of the plant with reference to general size, position, color, shape, and position of notches. After studying the stems above ground insert here any evident points of comparison. Do you find any special forms of stem development suited to a special purpose? Are there any organs in the nature of leaves?

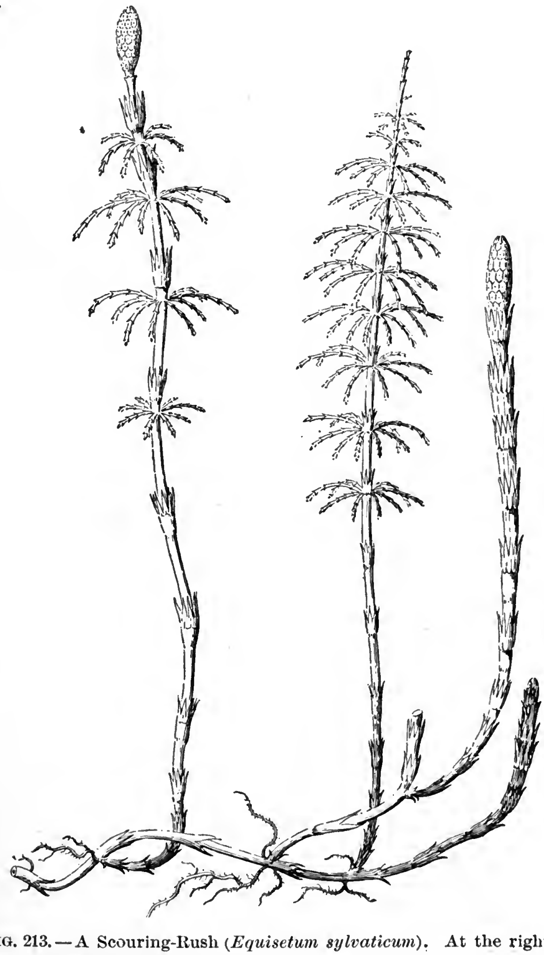


FIG. 213.—A Scouring-Rush (*Equisetum sylvaticum*). At the right is a colorless fertile stem, in the middle a green sterile one, and at the left a green fertile one.

361. Sterile Stems. — Examine the stems above ground with reference to their color and mode and degree of branching. What is the character of the leaves? Do the stems in any sense serve as leaves? Observe the nodes composing the stem and note the position of the leaves on the stems. Do they appear to be placed several at the same level (whorled)?

Examine with a magnifying glass the surface of the stem and note the number of ridges and grooves. Compare the number and position of the leaves with reference to these.

362. Mineral Matter in Stem. — Treat small pieces of the stem with strong nitric acid to remove all vegetable substance and note the mineral substance remaining. Treat in a similar way thin cross-sections and examine under the microscope. The substance is silica. It gives the plant its gritty feeling and its name and use as "scouring-rush." Of what use is it to the plant? Use of the same substance in outer rind of corn stem, bamboo stem, and straw of grains?

363. Microscopic Examination. — Make thin cross-sections of the stem and examine under the lowest power of the microscope. Make a diagrammatic sketch to indicate the central cavity, the number and position of the fibro-vascular bundles, the cavity or canal in each, the ring of tissue surrounding the ring of bundles, and the larger cavities or canals outside of this. Where is the chlorophyll located? Can stomata be found, and if so, what is their location and arrangement?

364. Fertile Stems. — Describe the fruiting stem with reference to general aspect, size, color, number, and length of internodes, position of spore-bearing portion, color of spores in mass. Note the shield-shaped bodies (transformed leaves or *sporophylls*) composing the cone-like "flower" and see whether any joints can be detected where they are attached. Examine the inner surface of the shields for sporangia and spores. Examine the sporangia under a low power of the microscope. Examine some spores under a higher power. Note the two bands, *elaters*, on each spore, crossing each other and attached only at the point of crossing, forming four loose appendages. Watch these while some one moistens them by gently breathing upon them as they lie uncovered on the slide under the microscope and note the effect. Also note the effect of drying. How does this affect the spores? Use of the bands?

365. Germination of Spores. — The spores germinate while fresh and form prothallia corresponding to those of ferns, but generally diœcious. The prothallium which bears the antheridia remains comparatively small, and the antheridia are somewhat sunken. The others grow much larger and branch profusely. The terminal portion becomes erect and ruffled. Near this part the archegonia are formed, quite similar to those of ferns. The embryo plant developing from the germ-cell has its first leaves in a whorl. This at length grows into a spore-plant like that shown in Fig. 213.

About twenty-five species of *Equisetum* are known. Several may be looked for in any locality and may well be compared with the one described above, in regard to form, mode of branching, and mode of fruiting.

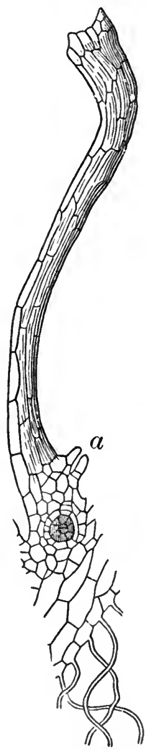


FIG. 214. — Part of a Lobe of the Mature Female Prothallium of *Equisetum*. (× about 50.) *a*, mouth of a fertilized archegonium.

366. Fern-Plants (Pteridophytes). — The *Pteridophytes* (literally fern-plants) include in their general category not only ferns as commonly recognized, but several other small groups which are very interesting on account of their diversity. All cryptogams higher than mosses belong in this group. In moss plants the individuals growing from spores and bearing antheridia and archegonia, the gametophytes, are full-grown leafy plants, and the spore-bearing plant, or sporophyte, is merely a stalk bearing a sporangium. In all the fern-plants the reverse is true. The individuals growing from spores and bearing antheridia and archegonia are of minor vegetative development (*prothallia*), while the spore-bearing plant is a leafy plant, even a tree in some ferns.

The ferns in the strictest sense have sporangia derived from the epidermis (transformed hairs), while a few plants closely resembling them in general aspect (*Botrychium*, etc.) have sporangia formed in the tissue of the leaf.

In the next subdivision, the water-ferns (Fig. 215), there is little resemblance to the common ferns. The sporangia are in special receptacles at the basal portion of the plant. The spores are of two kinds, *diœcious*, one on germination, producing antheridia, the other archegonia. This group includes two rooting forms, *Marsilea* (with leaves resembling a four-leaved clover) and *Pilularia*, bearing simple linear leaves, and two floating forms, *Salvinia* (Fig. 215) and *Azolla*.

The remaining groups of fern-plants are the horse-tails and the club-mosses. The horse-tails have only one kind of spore and are peculiar chiefly in their vegetative aspect (Fig. 213), while the spore-bearing leaves, or sporophylls, are arranged in the form of a cone, as already shown.

The club-mosses include some plants which, as their name implies, have a superficial resemblance to a large moss, with the addition of a club-shaped stalked fruiting spike. These are the so-called "ground pines" and the running ground "evergreens" used for Christmas festoons in New England. Technically the group is distinguished by the possession of firm-walled sporangia formed singly near the bases of the leaves. The ordinary club-mosses already referred to have but one kind of spore, while plants called *Selaginella* and *Isoetes* have two kinds of spores, in this respect resembling *Marsilea*. In many species of *Selaginella* the leaves are arranged flat-wise on the stem, so that considered physiologically the branching stem and its leaves together serve as a foliage leaf. In one of the commonest American forms, however, the stem is more nearly erect, and the leaves are all alike and four-ranked.

Isoetes (quill-wort) grows attached to the soil in shallow water at the bottoms of ponds. It has the aspect of short grass growing in bunches. The large sporangia are at the broad bases of the leaves.

367. High Organization of Pteridophytes. — The student may have noticed that in the scouring-rush and the club-moss studied there are groups of leaves greatly modified for the purpose of bearing the sporangia. These groups are more nearly equivalent to flowers than anything found in the lower spore-plants, and the fern-plants which show such structures deserve to be ranked just below seed-plants in any natural system of classification.

The variety of tissues which occur in pteridophytes is frequently nearly as great as is found in ordinary seed-plants, and the fibro-vascular system is even better developed in many ferns than in some seed-plants.

Starch-making is carried on by aid of abundant chlorophyll bodies contained in parenchyma-cells to which carbonic acid gas is admitted by stomata. In many cases large amounts of reserve food are stored in extensive root-stocks, so that the spring growth of leaves and stems is extremely rapid.

CHAPTER XXIII

THE EVOLUTIONARY HISTORY OF PLANTS

368. The Earliest Plant Life. — What sort of plants first appeared on the earth has never been positively ascertained. The oldest known rocks contain carbon (in the form of black lead or graphite) which may represent the remnants of plants charred at so high a temperature and under so great pressure as to destroy all traces of plant structure. Some objects supposed by many to be the remains of large algæ have been found in rocks that date back to a very early period in the life history of the earth, before there were any backboned animals, unless possibly some fishes. Judging from the way in which the various groups of plants have made their appearance from the time when we can begin clearly to trace their introduction upon the earth, it is probable that some of the simplest and lowest forms of thallophytes were the first to appear. Decaying animal or vegetable matter must have been less abundant than is now the case, so that a plant that could make part or all of its food from raw materials would have had a better chance than a saprophyte that could not. Water-plants are usually simpler than land-plants, so it is highly probable that some kind of one-celled aquatic alga was the first plant.

369. Fossil Plants. — *Fossils* are the remains or traces of animals or plants preserved in the earth by natural processes. Fossil plants, or parts of plants, are very common; the impressions of fern-leaves in bituminous coal and pieces of wood turned into a flint-like substance are two of the best known examples.

The only way in which we can get knowledge about the animals and plants that inhabited the earth's surface before men did is by studying such rocks as contain the remains of living things. In this way a great deal of information has been gained about early forms of animal life and a less amount about early plant life, — less because as a general thing plants have no parts that would be as likely to be preserved in the rocks as are the bones and teeth of the higher animals and the shells of many lower ones.

370. The Law of Biogenesis. — An extremely important principle established by the study of the development of animals and plants from the egg or the seed, respectively, to maturity is this: *The development of every individual is a brief repetition of the development of its tribe.* The principle just stated is known as the law of biogenesis. As eggs develop during the process of incubation, the young animals within for a considerable time remain much alike, and it is only at a comparatively late stage that the wing of the bird shows any decided difference from the fore-leg of the alligator or the turtle. Zoölogists in general are agreed that this likeness in the early stages of the life history of such different animals proves beyond reasonable doubt that they all have a common origin, that is, are descended from the same kind of ancestral animal.

Among plants the liverworts and ferns supply an excellent illustration of the same principle. In both of the groups the fertilized egg-cells, as the student may have learned by his own observations, are much alike. As the egg-cell grows and develops, the sporophyte of a liverwort, which proceeds from the egg-cell, is extraordinarily unlike the "fern" or asexual generation (sporophyte) among Filices. Now this progressive unlikeness between liverworts and ferns, as they develop from the fertilized egg-cell, points to the conclusion that both groups of plants have a common origin or that the more highly organized ferns are direct descendants of the less highly organized liverworts.

371. Plants form an Ascending Series. — All modern systems of classification group plants in such a way as to show a succession of steps, often irregular and broken, seldom leading straight upward, from very simple forms to highly complex ones. The humblest thallophytes are merely single cells, usually of microscopic size. Class after class shows an increase in complexity of structure and of function until the most perfectly organized plants are met with among the dicotyledonous angiosperms. During the latter half of the present century it first became evident to botanists that among plants *deep-seated resemblances imply actual relationship, the plants which resemble each other most are most closely akin by descent, and (if it were not for the fact that countless forms of plant life have wholly disappeared) the whole vegetable kingdom might have the relationships of its members worked out by a sufficiently careful study of the life histories of individual plants and the likeness and differences of the several groups which make up the system of classification.*[1]

[1] See Campbell's *Evolution of Plants* and Warming's *Systematic Botany*, Preface and throughout the work. In the little flora of the present book, the families are arranged in the order which, according to the best recent German authorities, most nearly represents their relationships.

372. Development of the Plant from the Spore in Green Algæ, Liverworts, and Mosses. — The course which the forms of plant life have followed in their successive appearance on the earth may be traced by the application of the law above named. Such algæ as the pond-scums produce spores which give rise directly to plants like the parent.

In many liverworts the spore by its germination produces a thallus which at length bears antheridia and archegonia. The fertilized archegonium develops into a sporophyte which remains attached to the thallus, although it is really a new organism. Liverworts, then, show an alternation of generations, one a sexual thallus, the gametophyte, the next a much smaller, non-sexual sporophyte, and so on.

A moss-spore in germination produces a thread-like protonema which appears very similar to green algæ of the pond-scum sort. This at length develops into a plant with stem and leaves, the sexual generation of the moss. The fertilized archegonium matures into a sporophyte which is the alternate, non-sexual generation. This is attached to the moss-plant, or gametophyte, but is an important new organism. In the moss, as in the liverwort, the sexual generation is the larger and the more complex ; the non-sexual generation being smaller and wholly dependent for its food supply on the other generation, to which it is attached.

373. Development of the Plant from the Spore in Pteridophytes. — In the pteridophytes there is an alternation of generations, but here the proportions are reversed, the prothallium, or sexual generation, or gametophyte, being short-lived and small (sometimes microscopic), and the non-sexual generation, the sporophyte, often being of large size. The ferns (non-sexual generation), for instance, are perennial plants, some of them tree-like.

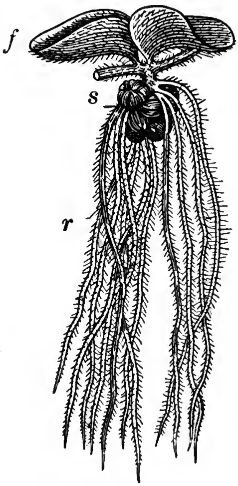


FIG. 215.—A Water-Fern (*Salvinia*).

Some pteridophytes, as the *Salvinia*, a small floating aquatic plant, sometimes known as a water-fern (Fig. 215), produce two kinds of spores, the large ones known as *macrospores*, and the small ones known as *microspores* (Fig. 216). Both kinds produce microscopic prothallia, those of the former bearing only archegonia, those of the latter only antheridia. From the prothallia of the macrospores a plant (non-sexual generation) of considerable complexity of structure is formed.

374. Parts of the Flower which correspond to Spores. — In seed-plants the spore-formation of cryptogams is represented, though in a way not at all evident without careful explanation. The pistil is the macrospore-producing leaf or *macrosporophyll*, and the stamen is the microspore-producing leaf or *microsporophyll*. Pines and other gymnosperms produce a large cell (the embryo sac) in the ovule (Fig. 217), which corresponds to the macrospore, and a pollen grain which represents the microspore. In its

FIG. 216.—Two Indusia of *Salvinia*. *mi*, microspores; *ma*, macrospores.

development the macrospore produces an endosperm which is really a small cellular prothallium, concealed in the ovule. The microspore contains vestiges of a minute prothallium.

In the angiosperms the macrospore and its prothallium are still less developed, and the microspore, or pollen grain, has lost all traces of a prothallium and is merely an antheridium which contains two generative cells.[1] These are most easily seen in the pollen grain, but sometimes they are plainly visible in the pollen tube (Fig. 164).

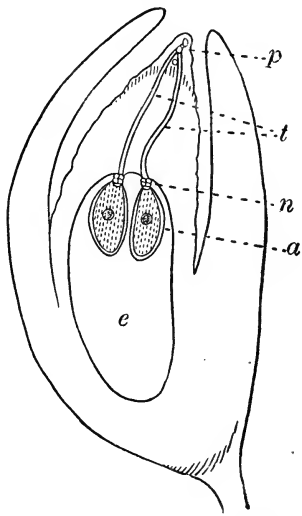


FIG. 217.—Longitudinal Section through Fertilized Ovule of a Spruce.

p, pollen grains; *t*, pollen tubes; *n*, neck of the archegonium; *a*, body of archegonium with nucleus; *e*, embryo sac filled with endosperm.

Phanerogams are distinguished from all other plants by their power of producing seeds, or enclosed macrosporangia, with embryos.

375. The Law of Biogenesis and the Relationships of the Great Groups of Plants.—On summing up Sects. 372–374 it is evident that the sexual generation in general occupies a less and less important share in the life of the plant as one goes higher in the scale of plant life.[2] In the case of the rockweed, for instance, the sexual generation is the plant. Among mosses and liverworts the sexual

[1] Sometimes only one generative cell escapes from the pollen grain into the pollen tube, and there it divides into two cells.

[2] A good many plants of low organization, however, are not known to pass through any sexual stage.

generation is still very prominent in the life of the plant. Ordinary ferns show us the sexual generation existing only as a tiny independent organism, living on food materials which it derives from the earth and air. In the *Salvinia* it is reduced to microscopic size and is wholly dependent on the parent-plant for support. Among seed-plants the sexual generation is so short-lived, so microscopic, and so largely enclosed by the tissues of the flower that it is comparatively hard to demonstrate that it exists.

The fact that the life history of so many of the classes of plants embraces a sexual stage, in which an egg-cell is fertilized by some sort of specialized cell produced wholly for use in fertilization, tends strongly to show the common origin of the plants of all such classes. We have reason to believe, from the evidence afforded by fossils, that plants which have only a sexual generation are among the oldest on the earth. It is therefore likely that those which spend the least portion of their entire life in the sexual condition were among the latest of plants to appear. Then, too, those which have the least developed sexual generation are among the latest of plants. Judged by these tests the angiosperms must be the most recently developed of all plants.

If one were to attempt to arrange all the classes of existing plants in a sort of branching series to show the way in which the higher plants have actually descended from the lower, he would probably put some one of the green algæ at the bottom and the angiosperms at the top of the series.

376. The Oldest Angiosperms. — It is impossible to give any of the reasons for the statements of this section without making an unduly long chapter. Briefly, it may be stated that the monocotyledons are the simplest and probably the oldest angiosperms; the dicotyledons are higher in organization and came later. The descent and various relationships of the families of dicotyledons can be discovered by the study of the flower, fruit, and seed better than by the examination of the vegetative organs.

The entire pedigree of the several families cannot be represented by arranging the names of the families in a straight line. It is, however, in a general way, as indicated by the succession of families in the Flora which accompanies this book, the Willow Family being perhaps the oldest (of the more familiar ones) and the Composite Family the youngest.

Part II

ECOLOGY

CHAPTER XXIV

PLANT SOCIETIES

377. Ecology. — Plant ecology includes all that portion of botany which has to do with the way in which plants get on with their animal and plant neighbors, and especially the way in which they adjust themselves to the nature of the soil and climate in which they live. Ecology, in short, discusses the relations of plants to their surroundings or environment. A good deal of what has been said in previous chapters about such topics as parasitic plants, the occurrence of winter bud-scales, the movements of leaves, the coating of hairs on stems and leaves, the storage of water in epidermis-cells, is really ecological botany, although it is not so designated in the sections where it occurs.

378. Plant Societies. — In a single acre of woodland, of marsh, or of meadow, there will usually be found a large number of species of plants. One species may be sufficiently abundant and conspicuous to give a name to the whole tract, so that it may, for instance, be recognized as a bit of birch wood or of cat-tail swamp. But under the birches and among the cat-tails there are plants, it may be, of a hundred other kinds, the seed-plants not all in bloom at any one season, but coming along in succession from earliest spring until the approach of winter. The entire set of plants which naturally occupies a given area of land under somewhat uniform conditions is called a *plant society*.

379. Similar Societies due to Similar Conditions. — As soon as the young botanist begins to collect plants in a set of localities new to him, he discovers that his old acquaintances are still to be found grouped as he has been accustomed to see them. The rich black loam of a wooded bank a hundred miles away from his familiar collecting ground will show the same assemblage of slippery elms and lindens, red buds, bladdernuts, and wahoos, hepaticas, bloodroots, Dutchman's breeches, trilliums, pepper root, and wild ginger, with a multitude of later-blooming herbaceous plants, that he has learned to know so well. The muddy borders of ponds from Maine to Minnesota and beyond are fringed with the same kinds of bur-reeds and sedges, set with water-plantain, and decorated with the soft white blossoms of the arrowhead. The sand dunes along the northern Atlantic coast and those that border Lake Michigan are clothed with a sparse vegetation which in both cases includes the little beach plum, such coarse grasses as that shown in Plate I, and the straggling sea rocket. Barnyards and waste grounds about farm buildings from Massachusetts to Missouri contain such weeds as the dog fennel, the low mallow ("cheeses"), motherwort, catnip, and some smartweeds.

A little study of such cases soon leads one to the conclusion that these plant societies and multitudes of others exist *because all the plants in each society are adapted to their special environment.* Wherever such an environment occurs such a society will be found in it,[1] or, if not already there, will flourish when introduced.

380. Similar Species replace Each Other. — Two sets of localities alike in many respects but unlike in some points are often inhabited by different species of the same genus. For instance, the pine barrens of New England and the adjacent states are commonly covered with the northern pitch pine, while far southward, in sandy soil, its place is taken by the long-leaved pine. Along streams and swamps northward the speckled alder is generally found, while southward the smooth alder is most common. In rich woods of the northeastern United States the painted trillium and the erect trillium ("Benjamin," or "squaw root") are the commonest species, while far south, in similar localities, the sessile trillium, Underwood's trillium, and the large-flowered trillium are abundant.

In all such cases — and they are very numerous — we are to infer that the genus is peculiarly well adapted to some especial set of conditions, as sandy soil, brooksides, or the rich, shaded soil of woodlands. But the more northerly species are capable of enduring the severe winters and brief summers of their region, while the more southerly ones perhaps cannot do so. The relative warmth of the climates in which they live may not be the only reason, or even the principal reason, for the distribution of such plants as those just mentioned, but it is one factor at any rate. And it is certain that, on the whole, most of our

[1] That is, in localities not separated by such natural barriers as seas, high mountains, or deserts.

native and thoroughly naturalized plants are growing under what is, for them, the best environment, since they cannot usually be made to exchange places with each other. If a square mile of land in Louisiana were to be planted with Minnesota species, and a square mile in Minnesota with Louisiana species, it is very improbable that either tract, if left to itself, would long retain its artificial flora. To this rule there are, however, important exceptions (see Sect. 457).

381. Plant Formations. — It is not uncommon to find tracts of land or water inhabited by great numbers of plants of the same species so as almost to exclude all other plants except microscopic cryptogams. Ponds and slowly flowing streams are often filled in this way with the water hyacinth or the American lotus. The cane-brakes of the south and the wild rice swamps along northern lakes and rivers are other examples of an extremely simple flora spread over large areas. Prairies not infrequently for hundreds of square miles are covered mainly (not entirely) with a very few kinds of grasses. Such assemblages are called *plant formations* or *plant colonies.*

382. Ecological Classification of Plants. — The ordinary classification of plants, as set forth in Chapter XIX, is based, as far as possible, on their actual relationships to each other. But when plants are classified ecologically they are grouped according to their relations to the world about them. They may, therefore, be gathered into as many (or more than as many) different groups as there are important factors influencing their modes of life. We may classify plants as light-loving and darkness-loving, as requiring free oxygen, and not requiring it, and so on.

Indeed, one of the most useful classifications of bacteria, for practical purposes, is into species which must have free oxygen, that is, oxygen not chemically combined with other substances, in order to grow and increase, and those which can live without it.

The most important consideration in classifying seed-plants on ecological grounds is based on their requirements in regard to water. Grouped with reference to this factor in their life all plants may be classed as:

(1) *Hydrophytes*, or water-loving plants.
(2) *Xerophytes*, or drought-loving (or perhaps drought-tolerating) plants.
(3) *Mesophytes*, or plants which thrive best with a moderate supply of water.

These three classes do not fully express all the relations of plants to the water supply, so two others are found convenient.

(4) *Tropophytes*, or seasonal plants which are hydrophytes during part of the year and xerophytes during another part.[1]
(5) *Halophytes*, or salt marsh plants and "alkali" plants, species which can flourish in a very saline soil.

383. Difficulties in Ecological Classification. — It seems at first sight a simple matter to group plants in regard to their need of water. There can be no difficulty in classifying as hydrophytes all plants like the bladderworts, water cresses, certain mosses, and many lower spore-plants which live only in water. Cactuses, aloes, and similar plants are recognized at sight as xerophytes. But the chief difficulty

[1] The plants which E. Warming, one of the foremost authorities, classes as mesophytes are many of them grouped by another great authority, A. F. W. Schimper, as tropophytes.

is in dividing mesophytes from the other two classes, into which they shade by indefinite gradations. In order to know whether the plants of a region have plenty of water or not, we must know not only how many inches of yearly rainfall there are, but also what the soil is like, what is the temperature of the soil and air, whether or not there are dry winds, and whether there are fogs or heavy dews. A lichen on a bare rock may be living almost under

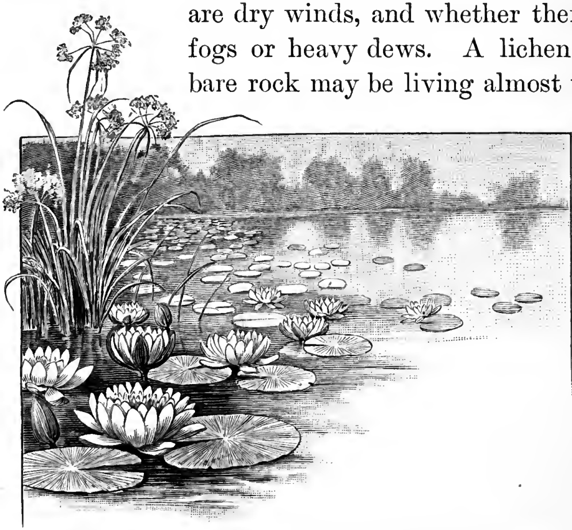


FIG. 218. — Aquatic Plants: Pond-Lilies with Floating Leaves and Sedges with Aërial Leaves.

desert conditions, while a pitcher-plant in a bog near by has its roots in standing water (or in ice) nearly all the year round.

384. Hydrophytes. — Some of these are herbaceous aquatic plants, like the duckweed, the pickerel-weed, the pond-lily, and the water-crowfoot; others, such as the "calla" (*Richardia*), the buckbean, the cat-tail, and the sweet flag, many ferns, mosses, and liverworts, prefer damp air and soil. All of them transpire freely, and many of them cannot live at all under the moisture conditions which suit ordinary plants.

Some aquatics have their leaves wholly submerged, others, such as the duckweed and the pond-lilies (Fig. 218), have them floating, and still others, like the sedges in the same picture, have their leaves freely exposed to the air. A few plants have both water-leaves and air-leaves (Fig. 219). Some aquatic plants are rooted in the mud, while others have no roots at all, or, like the duckweed, have only water-roots.

Fig. 219. — Submerged and Aërial Leaves of a European Crowfoot (*Ranunculus Purshii*). The leaf with thread-like divisions is the submerged one.

The leaves of land-plants in very rainy, subtropical climates are exposed to the attacks of parasitic spore-plants which flourish on their surfaces. To ward off the attacks of these it is necessary to keep water from accumulating on the surfaces of the leaves. This result is secured by a waxy deposit on the epidermis and also by the slender prolongation to drain off surplus water, shown in Fig. 221. That this slender leaf tip is useful in the way suggested is proved by the fact that when it is cut squarely off the leaf no longer sheds water freely.

385. Xerophytes. — A *xerophyte* is a plant which is capable of sustaining life with a very scanty supply of water. Since the first plants which existed were aquatics

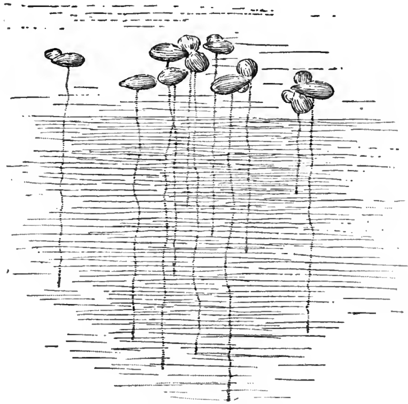


FIG. 220. — The Duckweed, a Floating Aquatic Plant.

(Sect. 368), we must consider that xerophytes are highly specialized and modified forms adapted to extremely trying conditions of life. A typical xerophyte is one which can live in a very dry soil in a nearly rainless region. The yucca in Plate VII and the melon-cactus (Fig. 49) are good examples of such plants. Less extremely xerophytic are plants like the date-palm (Fig. 54), which flourishes in the oases of the Sahara, where the soil is moist from the presence of springs, though rains are almost unknown, or the houseleeks and stonecrops found in many gardens, the so-called Spanish moss (Plate IV), and lichens (Figs. 198, 199), all of which grow most rapidly in moist air, but cling to bare rocks and trunks of trees, from which they get no water. A xerophyte must be capable of storing water and transpiring very slowly, like cactuses, aloes, stonecrops, and such fleshy plants

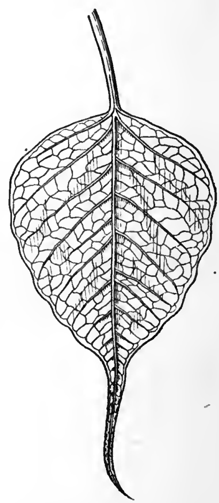


FIG. 221. — Leaf of an East Indian Fig Tree,[1] with a Slender Tapering Point to drain off Water.

[1] *Ficus religiosa.*

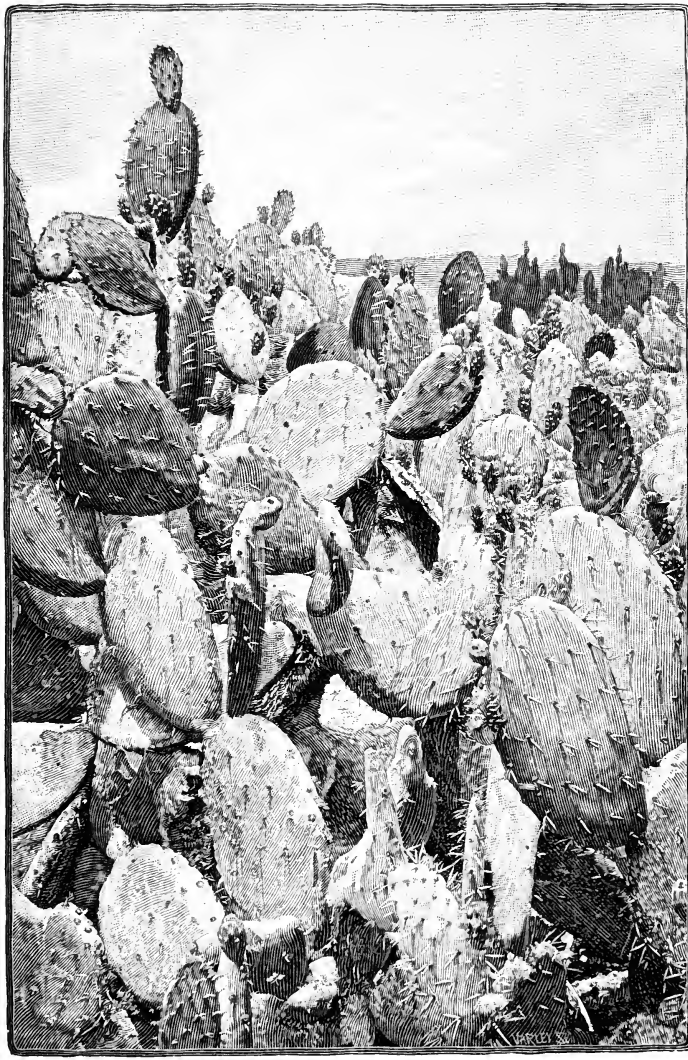


FIG. 222. — A Field of Prickly-Pear Cactus Plants : Xerophytes.

with a thick epidermis, or else it must be able to revive after being thoroughly dried. A few seed-plants and many such spore-plants as lichens, *Pleurococcus* (Sect. 277), yeast, and some bacteria (Sect. 263), thrive just as well after remaining for some months or years in a dried condition as they did before drying. A good illustration of this fact as regards yeast is found in the use of dried yeast cakes, made of a mixture of yeast and corn meal. These will raise dough promptly when mixed with it, even if they have been kept dry for a year or more.

FIG. 223. — *Harpagophytum*, a South African Xerophyte.

386. Roots and Stems of Xerophytic Seed-Plants. — Some xerophytes have roots which show no peculiarities of form or structure, but many make special provision for storing food and water in their roots. Such roots are fleshy and often, as in *Harpagophytum* (Fig. 223), are of great size compared with the portion of the plant above the ground.

Xerophytic stems are frequently very thick in proportion to their length, sometimes even globular, and they commonly contain large amounts of water. In leafless plants, like the cacti, the surface for transpiration is much less than that offered by leafy plants. Many species which bear leaves shed most of them at the beginning of the dry season, and some remain thus in a half dormant condition for long periods, as is the case with many *Euphorbias*

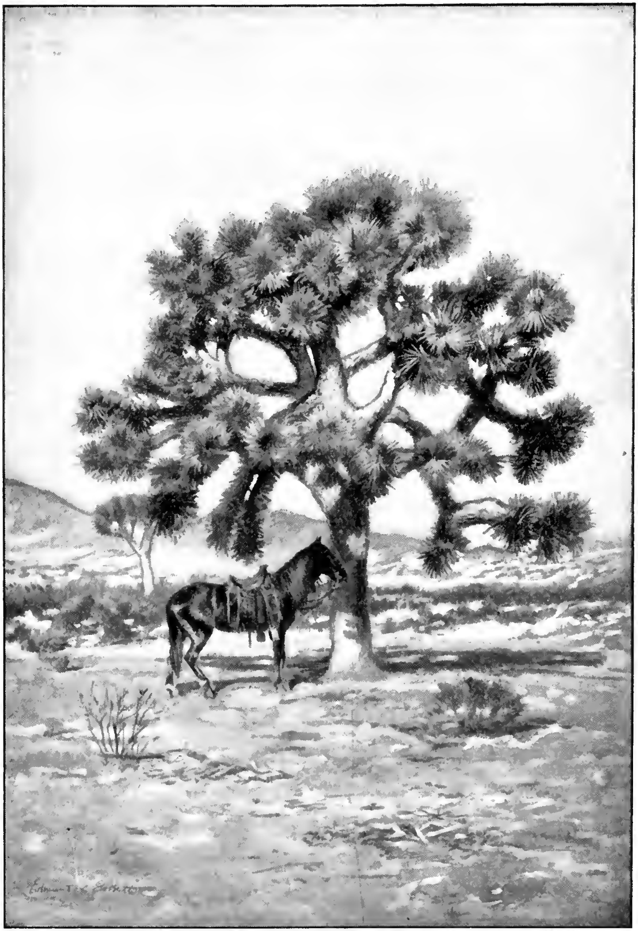


PLATE VII. — Tree Yucca in the Mohave Desert

(Fig. 245). The epidermis, even on the younger portions of the stem, is highly cutinized (Fig. 121), and this structure makes any evaporation very slow.

387. Leaves of Xerophytes. — In regions where the greatest dangers to vegetation arise from long droughts and the excessive heat of the sun, the leaves of plants usually offer much less surface to the sun and air than is the case in temperate climates. Sometimes the blade of the leaf is absent and the expanded petiole answers the purpose of a blade, or, again, foliage leaves are altogether lacking, as in the cactuses (Fig. 222), and the green outer layers of the stem do the work of the leaves.

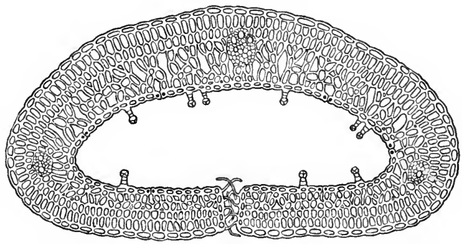


FIG. 224. — Cross-Section of Rolled-Up Leaf of Crow-Berry (*Empetrum nigrum*). (Magnified.)

388. Rolled-Up Leaves. — Leaves which receive but a scanty supply of water are often protected from losing it too rapidly by being rolled up, so that the evaporating, *i.e.*, stomata-containing, surface is on the inside of the roll. Sometimes, as in the crow-berry (Fig. 224), the curled condition is permanent. In other plants, as in such grasses as *Stipa* (Fig. 225), and in Indian corn, the leaf rolls up when the weather is very dry and unrolls again when it receives a better supply of water.

389. Mesophytes. — A mesophyte is a plant which thrives best with a moderate supply of water. The great majority of the wild and the cultivated plants of the United States are mesophytes, and what has been learned from Part I of this book about the forms, structure, and habits of ordinary plants, together with what the student's own observation, aside from the study of botany, has taught him, should suffice to give him a fair idea of mesophytic plant life.

The typical mesophyte of the northern United States is an annual, since most of our larger perennials pass the winter in a xerophytic condition, to avoid destruction by drying up during the long period when the roots can absorb little or no water from the frozen soil. Our evergreen coniferous trees, such as pines, spruces, cedars, and so on, have leaves of decidedly xerophytic structure. So also do such evergreen shrubs as the rhododendrons, wintergreen, arbutus, holly, and bearberry. Our deciduous trees and shrubs and most perennial herbs are tropophytes (Sect. 390).

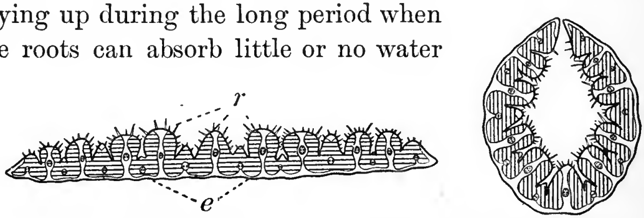


FIG. 225. — Cross-Section of Leaves of a Grass,[1] unrolled for Exposure to Sunlight and rolled up to prevent Evaporation.

r, ridges of the upper epidermis, with many stomata on their surfaces; *e*, thick lower epidermis, without stomata.

390. Tropophytes, or Seasonal Plants. — Examples of these are most deciduous trees and the majority of the perennials of temperate regions, for instance oaks, elms, birches among trees, and tulips, crown imperials, lilies, hyacinths, spring-beauties, peonies, dahlias, and potatoes among herbs. Such plants have a pretty large surface for

[1] *Stipa capillata.*

transpiration during the summer (or in regions like Southern California in the rainy season) and a greatly reduced surface during the winter (or the dry season).

In the case of trees the reduction of surface is brought about by the fall of the leaves (Sect. 186), and in the case of herbaceous perennials it is secured by the death of the green stem and the leaves, so that only a compact root, rootstock, or bulb is left alive underground. That is to say, the perishable or annual part of tropophytes has the characteristics of mesophytes or even of moisture-loving plants, while the perennial part is constructed on the plan of xerophytes.

391. Halophytes. — A halophyte is a plant which can thrive in a soil containing much common salt or other saline substances. The seaside obviously occurs to one as the region of halophytic vegetation, but many inland areas contain halophytic plants, for instance the neighborhoods about salt springs and the "alkali" lands of the southwest and the Pacific Slope. The presence of salt in the soil renders absorption of the soil-water comparatively difficult, since osmosis takes place more readily between ordinary water and the liquid

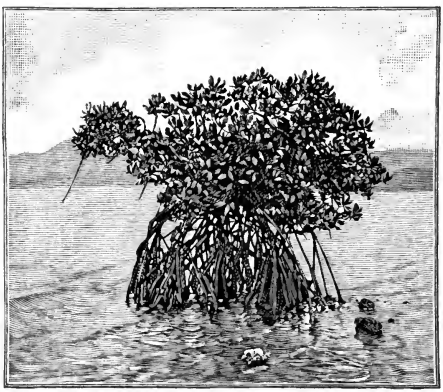


FIG. 226. — The Mangrove, a Halophytic Tree of Southern Florida and the Tropics.

contents of root-hairs and young roots than between salt water and the liquids inside the root. Halophytes, therefore, are put on short rations as regards water, even though they may be growing in a watery marsh. Consequently halophytes often have much the appearance of fleshy xerophytes and the structure of xerophytes.

The mangrove tree (Fig. 226) is one of the most remarkable of halophytes. It grows in shallow water along the seashore and sends out many aërial roots which at length find their way down into the salt mud. In this way it collects drift material and gradually extends the shore line farther out to sea.

392. Other Kinds of Ecological Classes. — It is easy to class plants according to their habits in many other regards than according to their relative power of transpiration (see Chapter XXVI). Only one other kind of classification need, however, be mentioned in this chapter, that is, the division into sun-loving and shade-loving plants. Even in very dense forests some plants will be found growing on the soil in the twilight formed by the shade of the trees. Some of this undergrowth is of seed-plants, and there are many ferns and mosses which flourish in such situations. Shade-plants commonly have large pale leaves, and generally (except in ferns) the leaves are not much cut or lobed (Fig. 227, I). Sun-loving plants, on the other hand, usually have comparatively little leaf-surface, and the leaves are often cut into narrow divisions (Fig. 227, II). Apparently the broad leaf-surfaces in the one class are to expose many green cells to the light for starch-making, while in the other class the slender leaf-divisions expose enough assimilating cells, and at the same time the narrowness of the division permits plenty of light to penetrate to the plant's lower leaves. It is also, doubtless, much easier for leaves like those of the yarrow, the dog fennel, the tansy, the carrot, and their like, to withstand the action of severe winds, to which they are often exposed, than it would be for leaves like those of the jack-in-the-pulpit (see Frontispiece), the trilliums, the lily-of-the-valley, and similar leaves.

FIG. 227. — I, a Shade-Plant (*Clintonia*); II, a Sun-Plant, Dog Fennel (*Maruta*).

393. Transition of a Plant from Shade Conditions to Sun Conditions. — It is characteristic of many kinds of forest trees that the young seedlings are much more tolerant of dense shade than the adult trees are. Sometimes their seeds will hardly germinate at all unless thoroughly shaded, and the young trees for the first few years flourish best in the shade. Afterwards most trees need a good deal of sunlight, but they may live long with a scanty supply of light. The red spruce sometimes

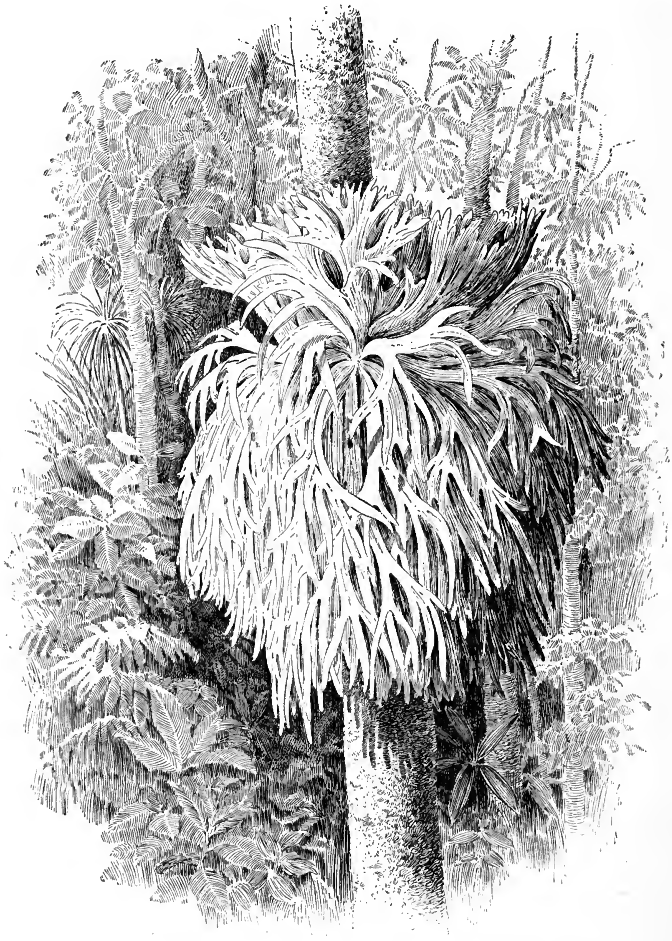


FIG. 228.—An Epiphytic Fern (*Platycerium*) on a Tree Trunk.

The more upright leaves next the trunk of the tree serve to collect water and to accumulate a deposit of decaying vegetable matter, while the outer leaves serve as foliage and bear spores.

lingers on for fifty or a hundred years, reaching meantime a diameter of not more than two inches, and then, on getting more light, shoots up into a large and valuable timber tree.[1]

394. Epiphytes. — It is even easier for a plant to secure enough sunlight in a forest region by perching itself upon the trunk or branches of a tree than by climbing, as our wild grapevines and the great tropical lianas do. There is a large number of such perched plants, or *epiphytes*, embracing species of many different groups of seed-plants and of spore-plants. The fern shown in Fig. 228 is a good example of an epiphyte. Instances among seed-plants are the so-called Florida moss (Plate IV) and orchids like those in Fig. 13.

[1] See the *Primer of Forestry*, Part I, U. S. Department of Agriculture, 1899, pp. 33–35.

CHAPTER XXV

BOTANICAL GEOGRAPHY

395. Regions of Vegetation. — The earth's surface (that of the land) has been described by one of the greatest of geographical botanists[1] as divided into twenty-four regions of vegetation. This classification takes account of all the principal continental areas which have a characteristic set of plants of their own, as well as of the most important islands. But a simpler arrangement is to consider the plant life of the earth as distributed among the following regions:

1. The tropical zone.
2. The temperate zones.
3. The arctic zones.
4. Mountain-heights.
5. Bodies of water.

Any good geography gives some account of at least the land vegetation of the earth. It is necessary in the present chapter only to point out a few of the most important characteristics of the plants of the zones and other areas mentioned above and to give some reasons why the plant population of each has its special characteristics.

396. Tropical Vegetation. — Within the tropics two of the great factors of plant life and growth, namely, light and heat, are found in a higher degree than elsewhere on the earth. Moisture, the third requisite, is in some

[1] A. Grisebach.

regions very abundant (over sixteen feet of rainfall in a year) or sometimes, in desert areas, almost lacking. We find here, accordingly, the greatest extremes in amount of vegetation, from the bare sands or rocks of the Sahara desert (Fig. 229) to the densely wooded basin of the Kongo and of the Amazon. Xerophytic plants, many of them with extremely complete adaptations for supporting life for long periods without water, are characteristic of tropical deserts, while many of the most decided hydrophytes among land-plants are found in the dripping sub-

FIG. 229. — Hills of Drifted Sand in the Sahara.

tropical forest interiors. Throughout a large part of the zone, reaching five degrees each way from the equator, there are daily rains the year round.

397. Vegetation of the Temperate Zones. — We are all familiar in a general way with the nature of the plant life of the north temperate zone; that of the south temperate is in most ways similar to our own. Most of the annuals and biennials are of a medium type, not decided xerophytes nor hydrophytes, and the perennials are mainly tropophytes. There are no desert areas so large or so nearly destitute of plants as those found in subtropical regions, neither are there any such luxuriant growths as occur in the rainy forest regions of the tropics. On the other hand, the largest trees on earth, the "big trees," or Sequoias (Fig. 32), occur in the temperate portion of North America, along the Sierra Nevada, and the taller, though less bulky, gum trees (*Eucalyptus*) of Australia grow in a warm temperate region.

398. Temperate Plant Societies due to Special Conditions of Soil. — Even where the climate is a moderate one as regards temperature and rainfall, peculiar soils may cause the assemblage of exceptional plant societies. Some of the most notable of such societies in temperate North America are those of the salt marshes, the sand dunes, and the peat bogs.

FIG. 230. — A Halophytic Plant (*Salicornia*).

In salt marshes the water supply is abundant, but plants do not readily absorb salt water by their roots, so that the plants which grow in salt marshes usually have something of the structure and appearance of xerophytes. Some of them are fleshy (Fig. 230), and some species are practically leafless.

Sand dunes, whether along the seacoast or near the great lakes, offer a scanty water supply to the roots during much of the year, and the soil-water contains less of the raw materials for plant food than is offered by that of ordinary soils. Many grasses thrive, however, in these shifting sands (Plate I), and some, like the beach-grass

(*Ammophila*) of the Atlantic coast and the great lakes, will continue to grow upward as the sand is piled about them by the winds until they have risen to a level of a hundred feet above the starting point.

Peat bogs are especially characterized by the predominance of the peat mosses (Fig. 231) from which they take their name. These plants and the others which associate with them are mostly hydrophytes, living usually with a considerable portion of the plant continually submerged in the bog water. The water of such bogs contains little mineral matter and only a very scanty supply of nitrogen, in the form of nitrates dissolved in it. The bog-plants, therefore, must either get on with an exceptionally small supply of nitrogen or they must get it from an unusual source. The peat mosses adopt the former alternative, while the sun dews (Fig. 238), the pitcher-plants (Fig. 237), and some other species adopt the latter and derive their nitrogen supply largely from insects which they catch, kill, and digest.

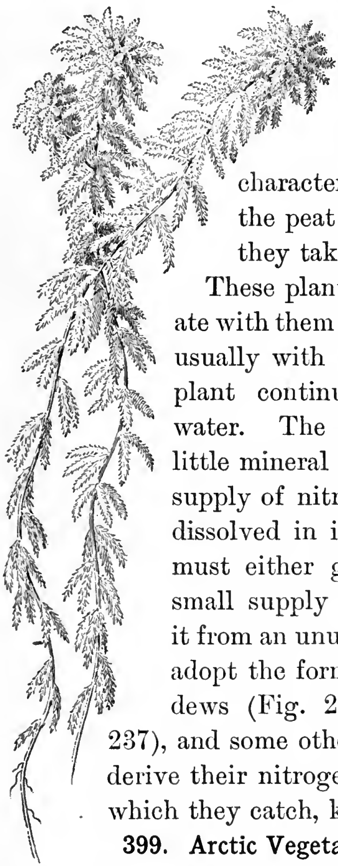


FIG. 231. Peat Moss.

399. Arctic Vegetation. — The seed-plants of the arctic flora are mostly perennials, never trees. By the large bulk of the underground portion as compared with that of the part above ground, they are adapted to a climate in which they must lie dormant for not less than nine months of the year. The flowers are often showy and appear very quickly after the brief summer begins. Mosses and lichens are abundant, — the latter of economical importance because they furnish a considerable part of the food of reindeer.

400. Mountain or Alpine Vegetation. — In a general way the effect of ascending a mountain, so far as vegetation is

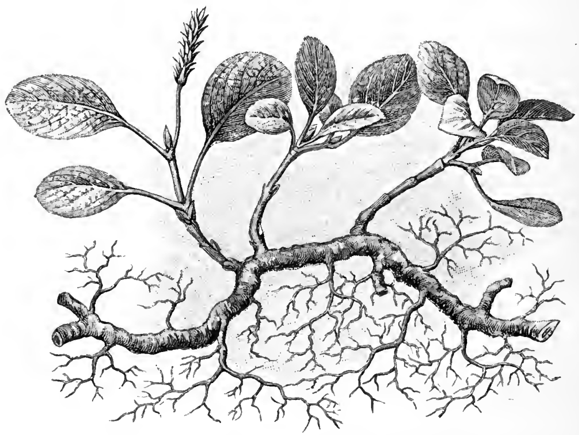


FIG. 232. — A Plant of Arctic Willow. (About natural size.)

concerned, is like that of traveling into colder regions. It was long ago suggested, in regard to Mount Ararat, that on ascending it one traversed first an Armenian, then a South European, then a French, then a Scandinavian, and finally an arctic flora. Up to a certain height, which varies in different latitudes, the slopes of mountains are very commonly forest-covered. The altitude up to which trees can grow (or as it is commonly called in this country the "timber line") is somewhat over twelve thousand feet in the equatorial Andes and lessens in higher latitudes as one goes either way from the equator. In the White Mountains, for instance, the timber line only rises to about four thousand five hundred feet. The seed-plants of alpine regions in all parts of the earth have a peculiar and characteristic appearance. It is easiest to show how such plants differ from those of the same species as they look when

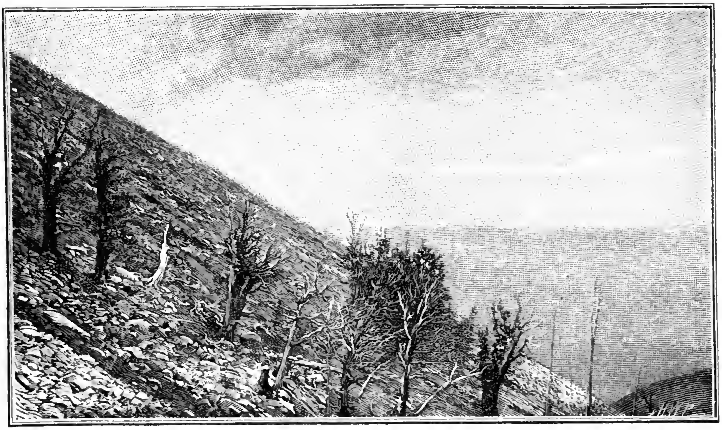


FIG. 233. — Trees near the Timber Line on the Slope of Pikes Peak.

growing in ordinary situations by reference to the plants themselves or to good pictures of them (see Fig. 235). The differences between alpine and non-alpine plants of the same or closely related species have been summed up as follows:[1]

"The alpine individuals have shorter stems, smaller leaves, more strongly developed roots, equally large or somewhat larger and usually somewhat more deeply colored flowers, and their whole structure is drought-loving (xerophilous)."

[1] By A. F. W. Schimper.

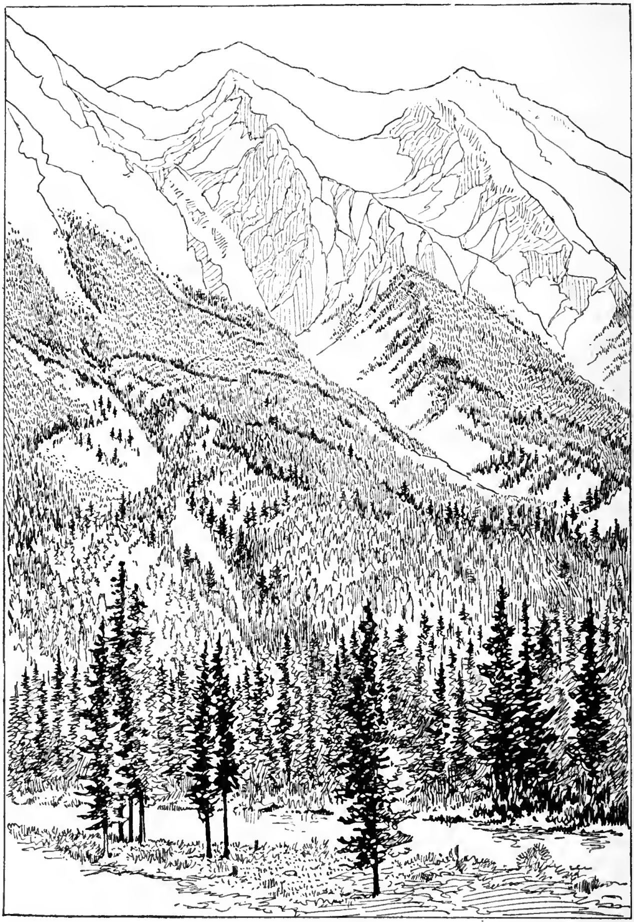


FIG. 234. — Decrease in Size of Trees at High Elevations (Canadian Rockies).

Trees at great elevations become much gnarled and stunted, as their growth is necessarily very slow (Fig. 233). The gradual diminution of the height of the trees on ascending a mountain is well shown in Fig. 234. The treeless character of the mountain summit is also plain.[1]

Recent experiments have shown that many ordinary plants promptly take on alpine characteristics when they are transferred to moderate heights on mountains. For instance, a rather commonly cultivated sunflower,[2] when planted at a height of about six thousand five hundred feet, instead of having a tall leafy stem produces a rosette of very hairy leaves lying close to the ground, thus becoming almost unrecognizable as a sunflower. The change was even greater than that shown in the rock rose (Fig. 235) cultivated by the same experimenter. The peculiarities of alpine plants appear to be due mainly to the intense light which they receive during the daytime,

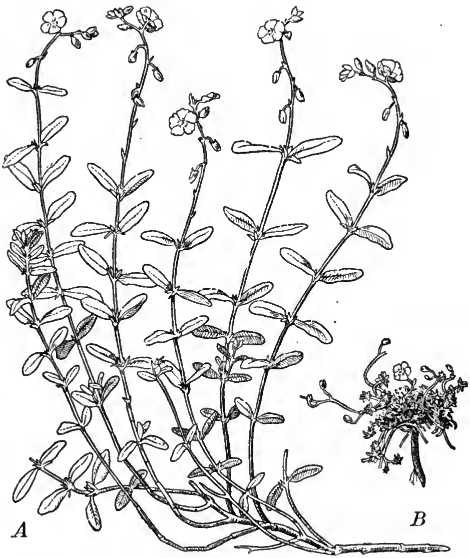


FIG. 235. — Two Plants of Rock Rose (*Helianthemum*). (Both drawn to the same scale.) *A*, low ground form ; *B*, alpine form.

[1] Part of the diminution is only apparent, — the effect of distance, — but the growth at the highest levels is often less than waist high.

[2] *Helianthus tuberosus*, the so-called Jerusalem artichoke.

to the strongly drying character of the air in which they grow (due partly to its rarefaction), and to the low temperature which they must endure every night.

401. Aquatic Vegetation. — Plants which live wholly in water often need a less complicated system of organs than land-plants. True roots may be dispensed with altogether, as in many seaweeds, in most fresh-water algæ, and in some seed-plants. A few such plants have mere hold-fasts that keep them from drifting with the waves or the current. Sometimes roots may, as in the duckweeds (Fig. 220), serve the purpose of a keel and keep the flat, expanded part of the plant from turning bottom up. The tissues that give strength to the stems and leaves of land-plants are not usually much developed in submerged aquatics, since the water supports the weight of such plants. In some algæ, as the common rockweed or bladder-wrack (Fig. 183), the weight of the plant is admirably buoyed up by large air-bladders. Transpiration is done away with, and whatever carbonic acid gas or oxygen is absorbed or given off passes directly through the cell-walls into the interiors of the cells. Generally water-plants do not reach any great size, but some species are the longest of known plants, *Macrocystis*, the great kelp of the Pacific Ocean, attaining, it is said, the length of a thousand feet or more. In spite of the moderate size of most algæ the total bulk in the various oceans must be extremely large. The Sargasso Sea alone, in the Atlantic Ocean, reaches most of the way from the Bahamas to the Azores and extends over seventeen degrees of latitude. The whole area is occupied by a nearly compact mass of floating seaweed.

Besides the comparatively well-known and readily seen larger algæ there is a great amount of vegetation floating in what is known as the *plankton.* This is a mass of microscopic animals and plants, found floating scum-like or submerged in fresh and in salt water and often accumulated in great quantities near shores, to which it is swept by the action of the wind and waves and currents. Much of the plant life of the plankton, both of fresh and of salt water, often consists of the flinty-shelled one-celled microscopic algæ known as diatoms (Fig. 176).

402. Botanical Geography of the United States. — All of the continuous territory of the United States[1] lies in the north temperate zone. There is material for a large volume in the discussion of the distribution of plants over our territory in this continent alone, but it is possible to sum up a mere outline of the matter in a very few words. Excluding the floras of many single mountains and mountain ranges, the land surface of the country may for botanical purposes be divided into four great areas, as follows:

1. *The Forest Region.* — This occupies the eastern and central portion of the United States. It is bounded on the west by an irregular line, most of which lies to the eastward of the hundredth meridian. In some places this forest boundary extends eastward across the Mississippi River, while in others it recedes from the river five hundred miles or more to the westward.

2. *The Great Plains Region.* — This extends westward from the region above named to the Rocky Mountain Plateau.

[1] That is, not counting in Alaska, our West Indian possessions, the Sandwich Islands, or the Philippines.

3. *The Pacific Highland Region.* — This includes the Rocky Mountains, the Sierra Nevada, and the various plateaus between them.

4. *The Pacific Slope.* — This extends from the Cascade Range and the Sierra Nevada to the sea.

403. Characteristics of the Four Regions. — The forest region is mainly remarkable for its great variety of hard-wood trees, of which it contains a larger number of useful species than any equal area of the earth with a temperate climate. In the northeasterly portion and in much of the southerly portion there are extensive forests of the cone-bearing evergreens, such as pines, spruces, hemlocks, and cedars. The vegetation is in general such as thrives in medium conditions as regards heat and rainfall.

The plains region is largely covered with grasses, many of them xerophytes. Some of the most characteristic plants associated with the grasses are Compositæ, such as sunflowers, rosin-weeds (*Silphium*), cone-flowers, gum-weeds (*Grindelia*), and blazing-stars (*Liatris*).

The Pacific highland region includes a very great variety of plant societies, from the heavily wooded mountain slopes and valleys to high sterile plains which are almost deserts. Cone-bearing evergreen trees are very characteristic of the forests. Great numbers of alpine species of herbs and shrubs are found on the mountains at and above the timber line. In the alkali regions, where the soil is too full of mineral salts to permit ordinary plants to grow, many kinds of xerophytes, such as the salty sage (*Atriplex*) and the greasewood (*Sarcobatus*), occur. In the southern portion cactuses abound.

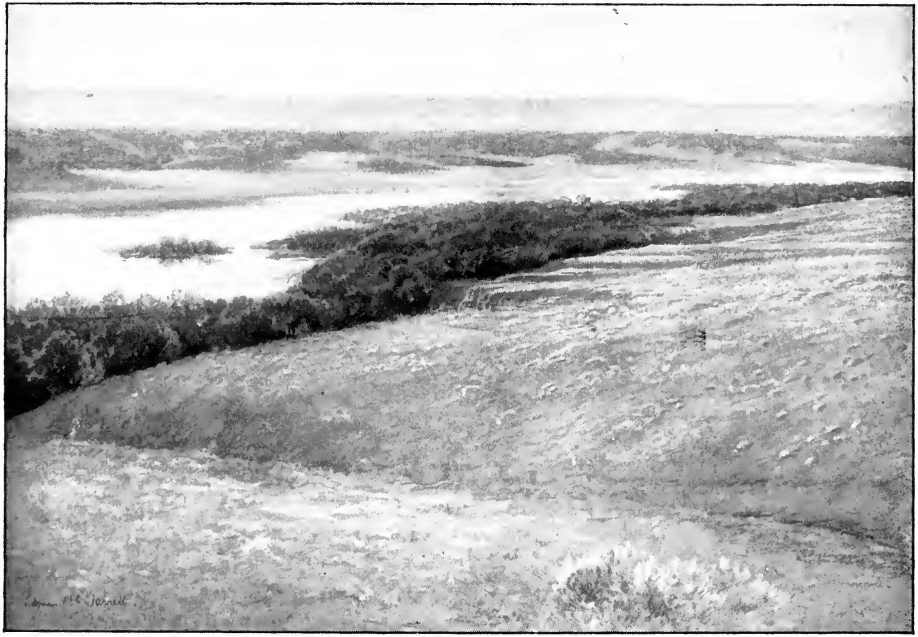


PLATE VIII. — Tree Belt along a Stream, Nebraska

The Pacific Slope is characterized by cone-bearing evergreens in great abundance in the mountains and along the foothills. Chief among these in point of size are the redwoods and the "big trees" (Sequoias) (Fig. 32). Oaks are represented by a good many species, several of them evergreen. There are many xerophytes, some of them characteristic of alkali regions; and in Southern California, on account of the long dry season, plants with large roots or rootstocks and bulb-bearing plants (many of them belonging to the lily family) are abundant. The tree yucca (Plate VII) is one of the largest and most interesting xerophytic plants of North America.

CHAPTER XXVI

PARASITES, ENSLAVED PLANTS, MESSMATES, CARNIVOROUS PLANTS

404. Parasites. — A little was said in Chapter IV about parasitic plants, and the life history of one of them, the dodder, was briefly outlined; another, the wheat rust, was discussed in Sects. 310–313. A *parasitic* plant is one which draws its supply of food partially or wholly from another living plant or animal known as the *host.* Some parasites are seed-plants, but a far greater number of species are spore-plants.

405. Half-Parasitic Seed-Plants. — Half-parasites or partial parasites are those which take a portion of their food (or of raw materials to make food) from their host and manufacture the rest for themselves. Usually they take mainly the newly absorbed soil-water from the host and do their own starch-making by combining the carbonic acid gas, which they absorb through their leaves, with the water stolen by the parasitic roots or *haustoria* imbedded in the wood of the host. Evidently the needed water may just as well be taken from the underground parts of the host as from the upper portions, and accordingly many half-parasites are parasitic on roots. This is the case with many of the beautiful false foxgloves (*Gerardia*), with the painted-cup (*Castillea*), and some species of bastard toad-flax (*Comandra*); see Flora. Usually these root-parasites are not recognized by non-botanical people as parasites at

Plate IX. — A Cottonwood covered with Mistletoe

all, but in Germany a species common in grain fields [1] and the eyebright, which abounds in grass fields, are respectively known as "hunger" and "milk-thief," from the injury they do to the plants on which they fasten themselves. The mistletoe is a familiar example of a half-parasite, which roots on branches (Plate IX). Among the scanty belts of cottonwood trees along streams in New Mexico it is necessary to lop off the mistletoe every year to give the tree any chance to grow. Half-parasites may be known from plants that are fully parasitic by having green or greenish foliage, while complete parasites have no chlorophyll and so are not at all green.

406. Wholly Parasitic Seed-Plants. — These are so nearly destitute of the power of assimilation that they must rob other plants of all needed food or die of starvation. Some, like the cancer-root (see Flora), are root-parasites; others, like the dodder, are parasitic on stems above ground. The most dependent species of all, such as the flax-dodder, can live on only one kind of host, while the coarse orange-stemmed dodder,[2] which is common all over the central and the northeastern states, grows freely on many kinds of plants, from golden-rods to willows.

407. Parasitic Cryptogams. — The wheat rust (Sect. 310) affords an excellent example of the relations between parasitic fungi and their hosts. The illustration showing the potato blight escaping from a stoma of the potato leaf (Fig. 191) shows plainly one way in which a microscopic parasite finds its way out of the tissues of the host-plant to ripen and scatter its spores.

[1] *Alectorolophus hirsutus.*
[2] *Cuscuta Gronovii.*

Perhaps the most interesting, certainly to us the most practically important, cases of parasitism are those in which the bodies of animals, and especially of men, are attacked by parasitic plants. Bacilli and other bacteria of many species (Sect. 263) are among the commonest parasites which use the bodies of animals as hosts, and two or three examples will serve to illustrate how they find a lodgment in the host.

Rich garden soil, the dust of stables, and a good many other sources often contain immense numbers of a bacillus[1] which causes lockjaw. A man in cleaning harness scratches his hand with a buckle, introduces the bacilli into his system, and is soon taken with an attack of lockjaw. Sewage water often swarms with the bacilli of typhoid fever[2] (Fig. 174). The people in a city drink unfiltered water from a river into which sewage has been allowed to run higher up stream, the bacilli multiply at a rapid rate in the intestines of those who have drunk the water, and many of them are taken sick with typhoid fever. The phlegm expectorated by consumptive patients is full of the consumption bacillus;[3] this phlegm becomes dried up on floors, streets, or sidewalks, it is breathed by every one in the form of fine dust, and in the lungs of many who breathe it colonies of the bacillus are formed and the disease (consumption) becomes established in these persons.

408. Enslaved Plants. — Cases in which one kind of plant is useful in procuring food (or the raw materials of food) for another kind are quite common.

The relations on which algæ and fungi live together in

[1] Bacillus tetani. [2] Bacillus typhi. [3] Bacillus tuberculosis.

the form of lichens have already been described (Sect. 331). It is not correct to describe the condition of such algæ as slavery if the term is meant to imply that they derive no benefit from the association. Perhaps serfdom is a

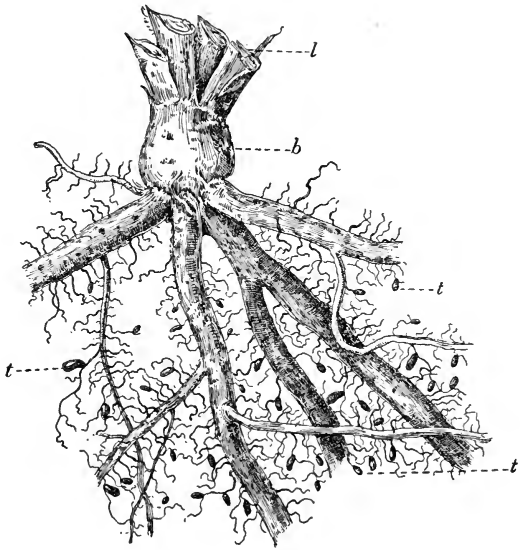


FIG. 236. — Roots of Red Clover with Tubercles.

l, sections of ascending branches; *b*, enlarged base of stem; *t*, root-tubercles containing bacteria.

more suitable word, though it is not the term used by botanists. At all events, the alga is enclosed within a network of fungus hyphæ from which it cannot readily escape, and there does most of the work of the lichen, including all of the manufacture of food from carbon dioxide.

409. Messmates.[1] — Plants of very diverse character, which live most intimately together to the advantage of both parties, may be called *messmates*, since in some fashion or other they divide the food supply between them.

FIG. 237. — Common Pitcher-Plant.[2]

At the right one of the pitcher-like leaves is shown in cross-section.

Bacteria live in colonies enclosed in root-tubercles on the roots of certain plants, for instance, beans, peas, lupines, vetches, and clover (Fig. 236), and render the greatest service to the plant to which the roots belong, from which they also derive food and shelter. Such plants do not develop root-tubercles and will not grow well in sterilized soil, that is, soil in which the bacteria have been killed by baking. It is found that the bacteria serve to change nitrogen taken from the air of the soil into nitric acid, which is a most important ingredient in the manufacture of proteids.

Many trees, for example, oaks, beeches, and the cone-

[1] This term is borrowed from the zoölogists as a much simpler one than *symbionts* to express the relation variously known as *symbiosis, commensalism,* or *mutualism.*

[2] *Sarracenia purpurea.*

FIG. 238. — Sundew (*Drosera rotundifolia*).

bearing evergreens, and a considerable number of herbaceous plants, such as the Indian pipe (*Monotropa*, Plate V), are covered with a growth of fungus hyphæ (Sect. 307).

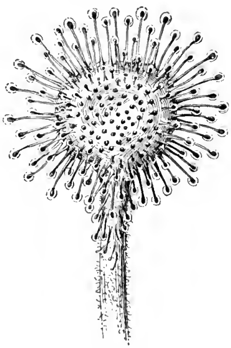


Fig. 239. — Blade of Leaf of Sundew. (Somewhat magnified.)

This growth completely surrounds the young, active tips of all the roots and the threads of the *mykorhiza*, as it is called, seem to do the work of root-hairs.

410. Carnivorous Plants. — In the ordinary pitcher-plants (Fig. 237) the leaf appears in the shape of a more or less hooded pitcher. These pitchers are usually partly filled with water, and in this water very many drowned and decaying insects are commonly to be found. The insects have flown or crawled into the pitcher, and, once inside, have been unable to escape on account of the dense growth of bristly hairs about the mouth, all pointing inward and downward. How much the common American pitcher-plants depend for nourishment on the drowned insects in the pitchers is not definitely known, but it is certain that some of the tropical species require such food.[1]

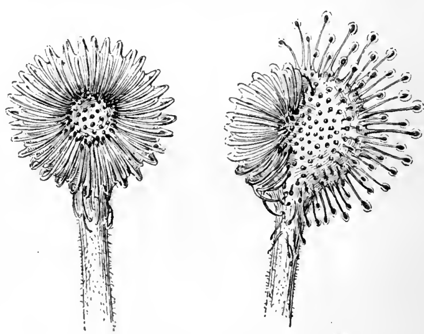


Fig. 240. — Leaves of Sundew. (Somewhat magnified.)

The one at the left has all its tentacles closed over captured prey; the one at the right has only half of them thus closed.

In other rather common plants, the sundews, insects are

[1] Where the *Sarracenia* is abundant it will be found interesting and profitable to make a careful class study of its leaves. See Geddes, *Chapters in Modern Botany*, Chapters I and II.

caught by a sticky secretion which proceeds from hairs on the leaves. In one of the commonest sundews the leaves consist of a roundish blade, borne on a moderately long petiole. On the inner surface and round the margin of the blade (Fig. 239) are borne a considerable number of short bristles, each terminating in a knob which is covered with a clear, sticky liquid. When a small insect touches one of the sticky knobs, he is held fast and the hairs at once begin to close over him, as shown in Fig. 240. Here he soon dies and then usually remains for many days, while the leaf pours out a juice by which the soluble parts of the insect are digested. The liquid containing the digested portions is then absorbed by the leaf and contributes an important part of the nourishment of the plant, while the undigested fragments, such as legs, wing-cases, and so on, remain on the surface of the leaf or may drop off after the hairs let go their hold on the captive insect.

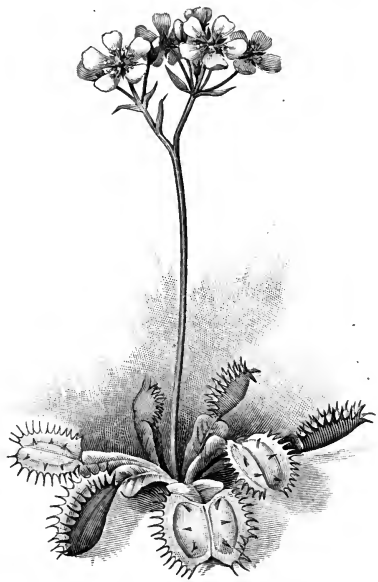


FIG. 241. — Venus Flytrap.

In the Venus flytrap, which grows in the sandy regions of eastern North Carolina, the mechanism for catching insects is still more remarkable. The leaves, as shown in

Fig. 241, terminate in a hinged portion which is surrounded by a fringe of stiff bristles. On the inside of each half of the trap grow three short hairs. The trap is so sensitive that when these hairs are touched it closes with a jerk and very generally succeeds in capturing the fly or other insect which has sprung it. The imprisoned insect then dies and is digested, somewhat as in the case of those caught by the sundew, after which the trap reopens and is ready for fresh captures.

411. Object of catching Animal Food. — It is easy to understand why a good many kinds of plants have taken to catching insects and absorbing the digested products. Carnivorous, or flesh-eating, plants belong usually to one of two classes as regards their place of growth ; they are bog-plants or air-plants. In either case their roots find it difficult to secure much nitrogen-containing food, that is, much food out of which proteid material can be built up. Animal food, being itself largely proteid, is admirably adapted to nourish the growing parts of plants, and those which could develop insect-catching powers would stand a far better chance to exist as air-plants or in the thin, watery soil of bogs than plants which had acquired no such resources.

CHAPTER XXVII

HOW PLANTS PROTECT THEMSELVES FROM ANIMALS

412. Destruction by Animals. — All animals are supported directly or indirectly by plants. In some cases the animal secures its food without much damaging the plant on which it feeds. Browsing on the lower branches of a tree may do it little injury, and grazing animals, if not numerous, may not seriously harm the pasture on which they feed. Fruit-eating animals may even be of much service by dispersing seeds (Sect. 453). But seed-eating birds and quadrupeds, animals which, like the hog, dig up fleshy roots, rootstocks, tubers or bulbs, and eat them, or animals which, like the sheep, graze so closely as to expose the roots of grasses or even of forest trees to be parched by the sun, destroy immense numbers of plants. So too with wood-boring and leaf-eating insects, and snails, which consume great quantities of leaves.

413. Some Modes of Protection from Animals. — Many of the characteristics of plants may be wholly or partly due to adaptations for protective purposes, while in particular cases we cannot be sure of the fact. Perching on lofty rocks or on branches of trees, burying the perennial part (bulb, rootstock, etc.) underground, growing in dense masses, like a canebrake or a thicket of blackberry bushes; all such habits of plants may be partly or altogether valuable to the plant as means of avoiding the attacks of animals, but this cannot be proved. On the other hand, there are plenty of instances of structures, habits, or accumulations of stored material in their tissue which plants seem to have acquired mainly or entirely as means of defense. Some of the most important are:

(1) The habit of keeping a bodyguard of ants.
(2) Mimicking the appearance of dangerous or uneatable plants, or imitating pebbles or earth, so that they may be overlooked.
(3) Forming tough, corky, woody, limy or flinty and therefore nearly uneatable tissue.
(4) Arming exposed parts with cutting edges, sharp or stinging hairs, prickles, or thorns.
(5) Accumulating unpleasant or poisonous substances in exposed parts.

414. Ant-Plants. — Some ants live on vegetable food, but most of them eat only animal food, and these latter are extremely voracious. It has been estimated by a careful scientist, an authority on this subject, that the ants of a single nest sometimes destroy as many as one hundred thousand insects in a day. The Chinese orange-growers in the Province of Canton have found how useful ants may be as destroyers of other insects, and so they place ant nests in the orange trees and extend bamboos across from one tree to another, to serve as bridges for the ants to travel on.

Certain tropical trees, in order to insure protection by ants, offer them especial inducements to establish colonies on their trunks and branches. The attractions which are offered to ants by various kinds of trees differ greatly. One of the most interesting adaptations is that of an acacia[1] (Fig. 242), which furnishes little growths at the ends of the leaflets which serve as ant food. These little

[1] *A. sphaerocephala.*

growths are known from their discoverer as Belt's bodies. The ants bore holes into the large hollow stipular thorns shown in the figure, live in these thorns, feed on the Belt's bodies, and protect the acacia from insect and other enemies. A nectary on the leaf furnishes additional food to the ant inhabitants of the tree. A great multitude of plants, some of them herbs, offer more or less important

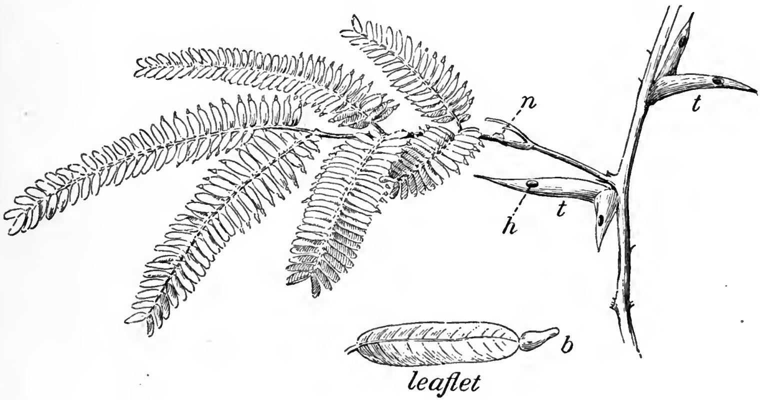


FIG. 242. — An Ant-Plant (*Acacia*).

t, thorns; *h*, hole in thorn; *n*, nectary; *b*, Belt's body on tip of leaflet.

inducements to attract ant visitors; the species which are known to do this number over three thousand.

415. Plants which mimic Plants or Other Objects. — Instances of mimicry of protected plants by unprotected species are not very common. One of the best-known cases is that of the dead-nettle, which is so called because it looks like the stinging nettle, though it is perfectly harmless. Some South African plants (*Kleinias*) appear to mimic pebbles. Certain Mesembryanthemums of the same region can hardly be distinguished from the earth in which they grow.

416. Plants of Uneatable Texture. — Whenever tender and juicy herbage is to be had, plants of hard and stringy texture are left untouched. The flinty-stemmed scouring-rushes (*Equisetum*, Sect. 361) and the dry, tough rushes are familiar examples of uneatable plants of damp soil. In pastures there grow such perennials as the bracken fern and the hardhack of New England and the ironweed and vervains of the Central States, which are so harsh and woody that the hungriest browsing

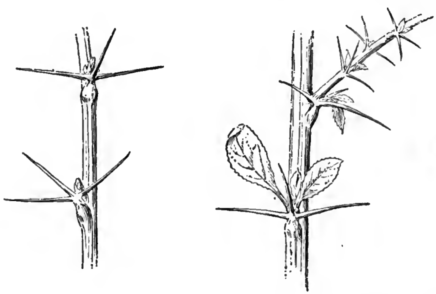


Fig. 243. — Spiny Leaves of Barberry.

animal is rarely, if ever, seen to molest them. Still other plants, like the knotgrass and cinquefoil of our dooryards, are doubly safe, from their growing so close to the ground as to be hard to graze and from their woody and unpalatable nature. The date-palm (which can easily be raised from the seed in the schoolroom or the laboratory) is an excellent instance of the same uneatable quality, found in a tropical or sub-tropical plant.

417. Plants with Weapons for Defense.[1] — Multitudes of plants, which might otherwise have been subject to the attacks of grazing or browsing animals, have acquired what have with reason been called weapons. Shrubs and trees not infrequently produce sharp-pointed branches, familiar in our own crab-apple, wild plum, thorn trees, and above all in the honey locust (Fig. 34), whose formidable thorns often branch in a very complicated manner.

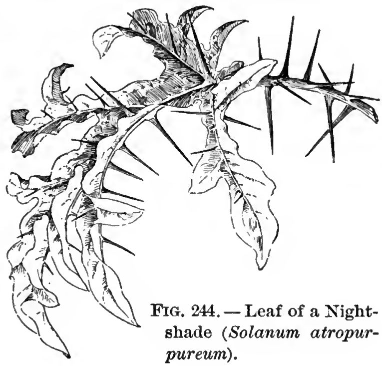


FIG. 244. — Leaf of a Nightshade (*Solanum atropurpureum*).

Thorns, which are really modified leaves, are very perfectly exemplified in the barberry (Fig. 243). It is much commoner to find the leaf extending its midrib or its veins out into spiny points, as the thistle does, or bearing spines or prickles on its midrib, as is the case with the nightshade shown in Fig. 244, and with so many roses. Prickles, which are merely hard, sharp-pointed projections from the epidermis, are of too common occurrence to need illustration.

Stipules are not infrequently found occurring as thorns, and in our common locust (Fig. 246) the bud, or the very young shoot which proceeds from it, is admirably protected by the jutting thorn on either side.

418. Pointed, Barbed, and Stinging Hairs. — Needle-pointed hairs are an efficient defensive weapon of many plants. Sometimes these hairs are roughened, like those

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. I, p. 430.

of the bugloss (Fig. 247, *b*); sometimes they are decidedly barbed. If the barbs are well developed they may cause the hairs to travel far into the flesh of animals and cause intense pain. In the nettle (Fig. 247, *a*) the hairs are efficient stings, with a brittle tip, which on breaking off

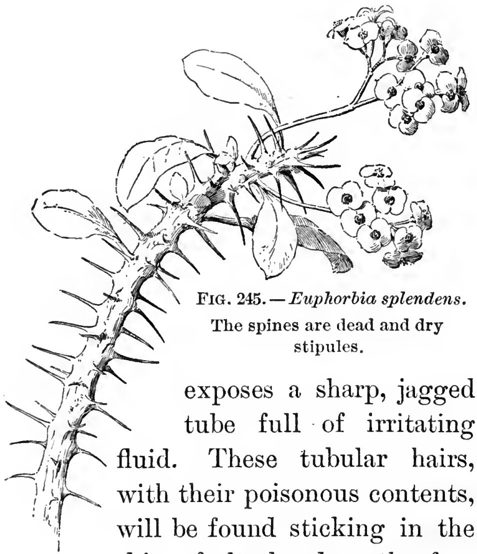


Fig. 245. — *Euphorbia splendens.* The spines are dead and dry stipules.

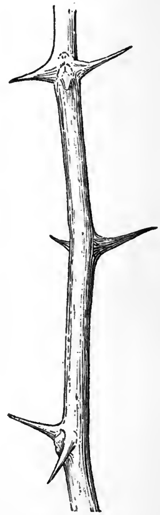


Fig. 246. — Thorn Stipules of Locust.

exposes a sharp, jagged tube full of irritating fluid. These tubular hairs, with their poisonous contents, will be found sticking in the skin of the hand or the face after incautious contact with nettles, and the violent itching which follows is only too familiar to most people.

419. Cutting Leaves. — Some grasses and sedges are generally avoided by cattle because of the sharp-cutting edges of their leaves, which will readily slit the skin of one's hand if they are drawn rapidly through the fingers. Under the microscope the margins of such leaves are seen to be regularly and thickly set with sharp teeth like those of a saw (Fig. 247, *c*, *d*).

420. Weapons of Desert Plants. — In temperate regions, where vegetation is usually abundant, such moderate means of protection as have just been described are generally sufficient to insure the safety of the plants which have developed them. But in desert or semi-desert regions the

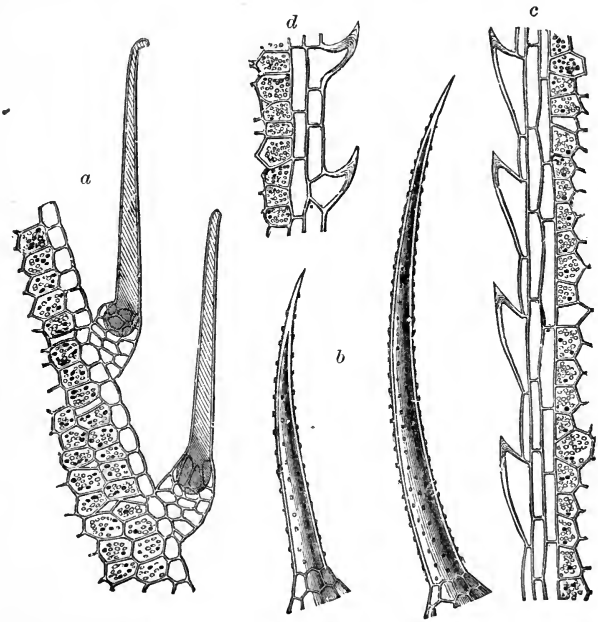


FIG. 247. — Stinging Hairs and Cutting Leaves. (All much magnified.)
a, stinging hairs on leaf of nettle; *b*, bristle of the bugloss; *c*, barbed margin of a leaf of sedge; *d*, barbed margin of a leaf of grass.

extreme scarcity of plant life exposes the few plants that occur there to the attacks of all the herbivorous animals that may encounter them. Accordingly, great numbers of desert plants are characterized by nauseating or poisonous qualities or by the presence of astonishingly developed thorns, while some combine both of these means of defense.

421. Offensive or Poisonous Plants. — A disgusting smell is one of the common safeguards which keep plants from being eaten. The dog fennel (Fig. 227), the hound's-tongue (*Cynoglossum*), the Martynia, and the tomato-plant are common examples of rank-smelling plants which are offensive to most grazing animals and so are let alone by them. Oftentimes, as in the case of the jimson weed (*Datura*), the tobacco-plant, and the poison hemlock (*Conium*), the smell serves as a warning of the poisonous nature of the plant.

A bitter, nauseating, or biting taste protects many plants from destruction by animals. Buckeye, horse-chestnut, and maple twigs and leaves are so bitter that browsing animals and most insects let them alone. Tansy, ragweed, boneset, southernwood, and wormwood are safe for the same reason. The nauseous taste of many kinds of leaves and stems, such as those of the potato, and the fiery taste of pepper-corns, red peppers, mustard, and horse-radish, make these substances uneatable for most animals. Probably both the smell and the taste of onions serve to insure the safety of the bulbs from the attacks of most grubs, and the hard corm of the jack-in-the-pulpit (*Arisæma*) (Frontispiece) is carefully let alone on account of the blistering nature of its contents.

Poisonous plants are usually shunned by grown-up animals, though the young ones will sometimes eat such plants and may be killed by them. Almost any part of a poisonous species may contain the poison characteristic of the plant, but, for obvious reasons, such substances are especially apt to be stored in the parts of the plant where its supply of reserve food is kept.

CHAPTER XXVIII

ECOLOGY OF FLOWERS

422. Topics of the Chapter. — The ecology of flowers is concerned mainly with the means by which the transference of pollen or *pollination* is effected, and with the ways in which pollen is kept away from undesirable insect visitors and from rain.

423. Cross-Pollination and Self-Pollination. — It was long supposed by botanists that the pollen of any perfect flower needed only to be placed on the stigma of the same flower to insure satisfactory fertilization. But in 1857 and 1858 the great English naturalist, Charles Darwin, stated that certain kinds of flowers were entirely dependent for fertilization on the transference of pollen from one plant to another, and he and other botanists soon extended the list of such flowers until it came to include most of the showy, sweet-scented, or otherwise conspicuous kinds. It was also shown that probably nearly all attractive flowers, even if they can produce some seed when self-pollinated, do far better when pollinated from the flowers of another plant of the same kind.[1] This important fact was established by a long series of experiments on the number and vitality of seeds produced by a flower when treated with its own pollen, or *self-pollinated*, and when

[1] See Darwin's *Cross and Self-Fertilization in the Vegetable Kingdom* (especially Chapters I and II).

treated with pollen from another flower of the same kind, or *cross-pollinated.*[1]

424. Wind-Pollinated Flowers.[2] — It has already been mentioned that some pollen is dry and powdery, and other kinds are more or less sticky. Pollen of the dusty sort is light, and therefore adapted to be blown about by the wind. Any one who has been much in corn-fields after the corn has "tasseled" has noticed the pale yellow dusty pollen which flies about when a cornstalk is jostled, and which collects in considerable quantities on the blades of the leaves. Corn is monœcious, but fertilization is best accomplished by pollen blown from the "tassel" (stamens) of one plant being carried to the "silk" (pistils) of another plant. This is well shown by the fact, familiar to every observing farmer's boy, that solitary cornstalks, such as often grow very luxuriantly in an unused barnyard or similar locality, bear very imperfect ears or none at all. The common ragweed, another monœcious plant, is remarkable for the great quantities of pollen which shake off it on to the shoes or clothes of the passer-by, and it is wind-pollinated. So, too, are the monœcious pines, and these produce so much pollen that it has been mistaken for showers of sulphur, falling often at long distances from the woods where it was produced. The pistil of wind-pollinated flowers is often feathery and thus adapted to catch flying pollen-grains (Fig. 248). Other

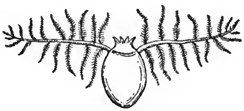


FIG. 248. — Pistil of a Grass, provided with a Feathery Stigma, adapted for Wind-Pollination.

[1] On dispersion of pollen see Kerner and Oliver, Vol. II, pp. 129–287.
[2] See Miss Newell's *Botany Reader*, Part II, Chapter VII.

characteristics of such flowers are the inconspicuous character of their perianth, which is usually green or greenish, the absence of odor and of nectar, the regularity of the corolla, and the appearance of the flowers before the leaves or their occurrence on stalks raised above the leaves.

Pollen is, in the case of a few aquatic plants, carried from flower to flower by the water on which it floats.

425. Insect-Pollinated Flowers. — Most plants which require cross-pollination depend upon insects as pollen-carriers,[1] and it may be stated as a general fact that the showy colors and markings of flowers and their odors all serve as so many advertisements of the nectar (commonly but wrongly called honey) or of the nourishing pollen which the flower has to offer to insect visitors.

Many insects depend mainly or wholly upon the nectar and the pollen of flowers for their food. Such insects usually visit during any given trip only one kind of flower, and therefore carry but one kind of pollen. Going straight from one flower to another with this, they evidently waste far less pollen than the wind or water must waste. It is therefore clearly advantageous to flowers to develop such adaptations as fit them to attract insect visitors, and to give pollen to the latter and receive it from them.

426. Pollen-Carrying Apparatus of Insects.[2] — Ants and some beetles which visit flowers have smooth bodies, to which little pollen adheres, so that their visits are often of slight value to the flower, but many beetles, all butterflies and moths, and most bees have bodies roughened with scales or hairs which hold a good deal of pollen entangled.

[1] A few are pollinated by snails; many more by humming-birds and other birds.

[2] See Müller's *Fertilization of Flowers*, Part II.

In the common honey-bee (and in many other kinds) the greater part of the insect is hairy, and there are special collecting baskets, formed by bristle-like hairs, on the hind legs (Fig. 249). It is easy to see the load of pollen accumulated in these baskets after such a bee has visited several flowers. Of course the pollen which the bee packs in the baskets and carries off to the hive, to be stored for food, is of no use in pollination. In fact such pollen is in one sense entirely wasted. But since such bees as have these collecting baskets are the most industrious visitors to flowers, they accomplish an immense share of the work of pollination by means of the pollen grains which stick to their hairy coats and are then transferred to other flowers of the same kind next visited by the bee.

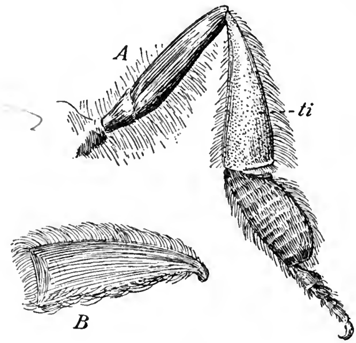


FIG. 249.

A, right hind leg of a honey-bee (seen from behind and within); *B*, the tibia, *ti*, seen from the outside, showing the collecting basket formed of stiff hairs.

427. Nectar and Nectaries. — Nectar is a sweet liquid which flowers secrete for the purpose of attracting insects. After partial digestion in the crop of the bee, nectar becomes honey. Those flowers which secrete nectar do so by means of *nectar glands*, small organs whose structure is something like that of the stigma, situated often near the base of the flower, as shown in Fig. 250. Sometimes the nectar clings in droplets to the surface of the nectar glands; sometimes it is stored in little cavities or pouches called *nectaries.* The pouches at the bases of columbine petals are among the most familiar of nectaries.

428. Odors of Flowers. — The acuteness of the sense of smell among insects is a familiar fact. Flies buzz about the wire netting which covers a piece of fresh meat or a dish of syrup, and bees, wasps, and hornets will fairly besiege the window screens of a kitchen where preserving is going on. Many plants find it possible to attract as many insect visitors as they need without giving off any scent, but small flowers, like the mignonette, and night-blooming ones, like the white tobacco and the evening primrose, are sweet-scented to attract night-flying moths. It is interesting to observe that the majority of the flowers which bloom at night are white, and that they are much more generally sweet-scented than flowers which bloom during the day. A few flowers are carrion-scented (and purplish or brownish colored) and attract flies.

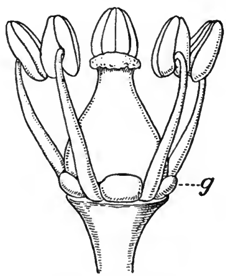


FIG. 250. — Stamens and Pistil of the Grape (magnified), with a Nectar Gland, *g*, between Each Pair of Stamens.

429. Colors of Flowers. — Flowers which are of any other color than green probably in most cases display their colors to attract insects, or occasionally birds. The principal color of the flower is most frequently due to showy petals; sometimes, as in the marsh marigold, it belongs to the sepals; and not infrequently, as in some cornels and Euphorbias (Fig. 245), the involucre is more brilliant and conspicuous than any part of the flower strictly so called.

Different kinds of insects appear to be especially attracted by different colors. In general, dull yellow, brownish, or dark purple flowers, especially if small, seem to depend largely on the visits of flies. Red, violet, and blue are the colors by which bees and butterflies are most readily enticed. The power of bees to distinguish colors has been shown by a most interesting set of experiments in which daubs of honey were put on slips of glass laid on separate pieces of paper, each of a different color, and exposed where bees would find them.[1]

It is certain, however, that colors are less important means of attraction than odors from the fact that insects are extremely near-sighted. Butterflies and moths cannot see distinctly at a distance of more than about five feet, bees and wasps at more than two feet, and flies at more than two and a fourth feet. Probably no insects can make out objects clearly more than six feet away.[2] Yet it is quite possible that their attention is attracted by colors at distances greater than those mentioned.

430. Nectar Guides. — In a large number of cases the petals of flowers show decided stripes or rows of spots, of a color different from that of most of the petal. These commonly lead toward the nectaries, and it is possible that such markings point out to insect visitors the way to the nectaries. Following this course, the insect not only secures the nectar which he seeks, but probably leaves pollen on the stigma and becomes dusted with new pollen, which he carries to another flower.

431. Facilities for Insect Visits. — Regular polypetalous flowers have no special adaptations to make them singly

[1] See Lubbock's *Flowers, Fruits, and Leaves,* Chapter I. On the general subject of colors and odors in relation to insects, see Müller's *Fertilization of Flowers,* Part IV.

[2] See Packard's *Text-Book of Entomology,* p. 260.

accessible to insects, but they lie open to all comers. They do, however, make themselves much more attractive and afford especial inducements in the matter of saving time to flower-frequenting insects by being grouped. This purpose is undoubtedly served by dense flower-clusters, especially by heads like those of the clovers and by the peculiar form of head found in so-called composite flowers, like the sunflower, the bachelor's button, and the yarrow (Fig. 133). In many such clusters the flowers are specialized, some carrying a showy strap-shaped corolla, to serve as an advertisement of the nectar and pollen contained in the inconspicuous tubular flowers (see Plate XI). Irregular flowers probably always are more or less adapted to particular insect (or other) visitors. The adaptations are extremely numerous; — here only a very few of the simpler ones will be pointed out. Where there is a drooping lower petal (or, in the case of a gamopetalous corolla, a lower lip), this serves as a perch upon which flying insects may alight and stand while they explore the flower, as the beetle is doing in Fig. 251. In Fig. 252 one bumblebee stands with his legs partially encircling the lower lip of the dead-nettle flower, while another perches on the sort of grating made by the stamens of the horse-chestnut flower. The honey-bee entering the violet clings to the beautifully bearded portion of the two lateral petals, while it sucks the nectar from the *spur* beneath.

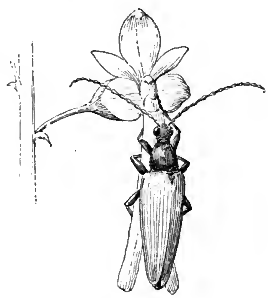


FIG. 251. — A Beetle on the Flower of the Twayblade. (Enlarged three times.)

432. Protection of Pollen from Unwelcome Visitors. — It is usually desirable for the flower to prevent the entrance of small creeping insects, such as ants, which carry little pollen and eat a relatively large amount of it. The means adopted to secure this result are many and curious. In

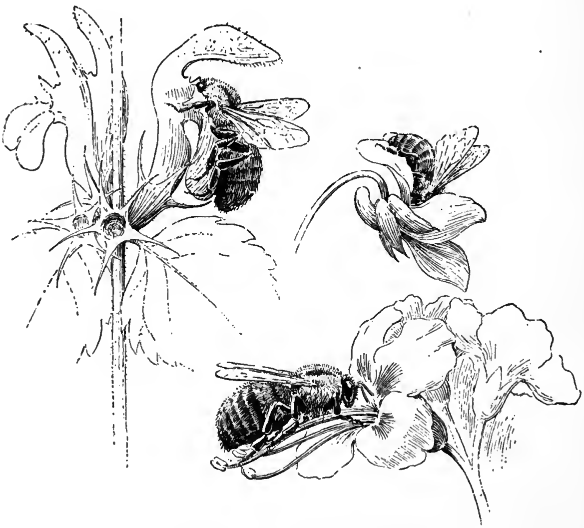


FIG. 252. — Bees visiting Flowers.

At the left a bumblebee on the flower of the dead nettle; below a similar bee in the flower of the horse-chestnut; above a honey-bee in the flower of a violet.

some plants, as the common catchfly, there is a sticky ring about the peduncle, some distance below the flowers, and this forms an effectual barrier against ants and like insects. Very frequently the calyx tube is covered with hairs, which are sometimes sticky. How these thickets of hairs may appear to a very small insect can perhaps be more easily realized by looking at the considerably magnified view of the hairs from the outer surface of mullein petals, shown in Fig. 253.[1]

Sometimes the recurved petals or divisions of the corolla stand in the way of creeping insects. In other cases the

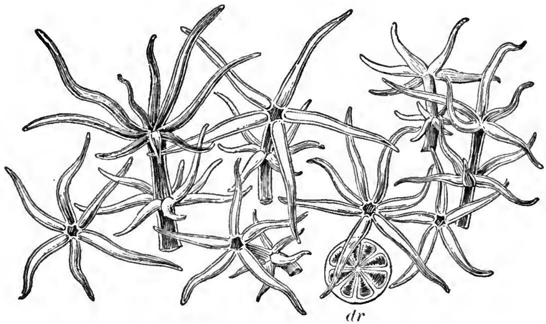


FIG. 253. — Branching Hairs from the Outside of the Corolla of the Common Mullein. (Magnified.) *dr*, a gland.

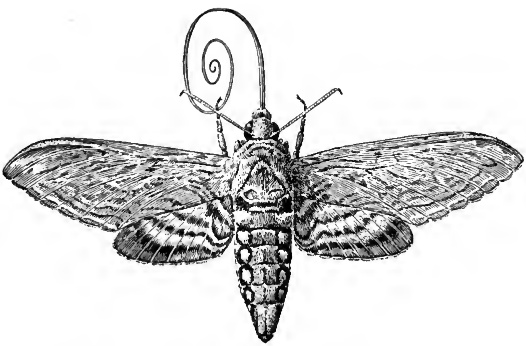


FIG. 254. — A Sphinx Moth, with a Long Sucking-Tube.

throat of the corolla is much narrowed or closed by hairs, or by appendages. Those flowers which have one or more

[1] On protection of pollen, see Kerner and Oliver, Vol. II, pp. 95-109.

sepals or petals prolonged into spurs, like the nasturtium and the columbine, are inaccessible to most insects except those which have a tongue or a sucking-tube long enough to reach to the nectary at the bottom of the spur. The large sphinx moth, shown in Fig. 254, which is a common visitor to the flowers of the evening primrose, is an example of an insect especially adapted to reach deep into long tubular flowers.

A little search among flowers, such as those of the columbine or the foxglove, will usually disclose many which have had the corolla bitten through by bees, which are unable to get at the nectar by fair means or unwilling to take the trouble to do so; and they therefore steal it.

433. Bird-Pollinated Flowers. — Some flowers with very long tubular corollas depend entirely upon birds to carry their pollen for them. Among garden flowers the gladiolus, the scarlet salvia, and the trumpet honeysuckle are largely dependent upon humming-birds for their pollination. The wild balsam or jewel-weed and the trumpet-creeper (Plate X) are also favorite flowers of the humming-bird.

434. Prevention of Self-Fertilization. — Diœcious flowers are of course quite incapable of self-pollination. Pistillate monœcious flowers may be pollinated by staminate ones on the same plant, but this does not secure as good seed as is secured by having pollen brought to the pistil from a different plant of the same kind.

In perfect flowers self-pollination would commonly occur unless it were prevented by the action of the essential organs or by something in the structure of the flower. In reality many flowers which at first sight would appear to be designed to secure self-pollination are almost or quite

PLATE X. — Humming Bird visiting Trumpet Creeper

incapable of it. Frequently the pollen from another plant of the same species prevails over that which the flower may shed on its own pistil, so that when both kinds are placed on the stigma at the same time it is the foreign pollen which causes fertilization. But apart from this fact there are several means of insuring the presence of foreign pollen, and only that, upon the stigma, just when it is mature enough to receive pollen tubes.

435. Stamens and Pistils maturing at Different Times. — If the stamens mature at a different time from the pistils, self-pollination is as effectually prevented as though the plant were diœcious. This unequal maturing or *dichogamy* occurs in many kinds of flowers. In some, the figwort and the common plantain for example, the pistil develops before the stamens, but usually the reverse is the case. The *Clerodendron*,[1] a tropical African flower (Fig. 255), illustrates in a most striking way the development of stamens before the pistil. The insect visitor, on its way to the nectary, can hardly fail to brush against the protruding stamens of the flower in its earlier stage (at *A*), but it cannot deposit any pollen on the stigmas,

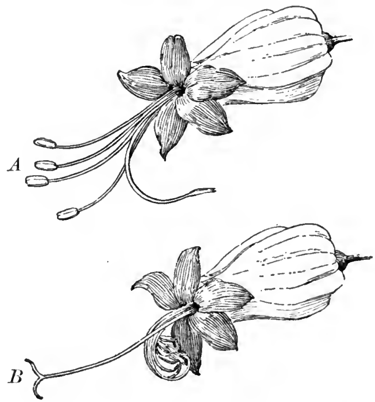


FIG. 255. — Flower of *Clerodendron* in Two Stages.

In *A* (earlier stage) the stamens are mature, while the pistil is still undeveloped and bent to one side. In *B* (later stage) the stamens have withered and the stigmas have separated, ready for the reception of pollen.

[1] *C. Thompsoniæ.*

which are unripe, shut together, and tucked aside out of reach. On flying to a flower in the later stage the pollen just acquired will be lodged on the prominent stigmas and thus produce the desired cross-pollination.

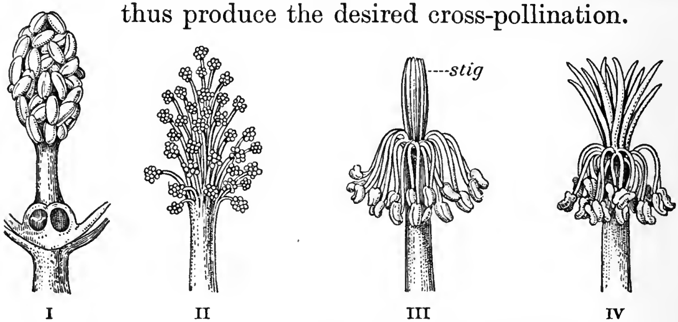


FIG. 256.—Provisions for Cross-Pollination in the High Mallow.

I, essential organs as found in the bud; II, same in the staminate stage, the anthers discharging pollen, pistils immature; III, intermediate stage, *stig*, the united stigmas; IV, pistillate stage, the stigmas separated, stamens withered.

Closely related flowers often differ in their plan of pollination. The high mallow, a plant cultivated for its purplish flowers, which has run wild to some extent, is admirably adapted to secure cross-pollination, since when its stamens are shedding pollen, as in Fig. 256, II, the pistils are incapable of receiving it, while when the pistils are mature, as at IV, the stamens are quite withered. In the common low mallow of our dooryards and waysides insect pollination may occur, but if it does not the curling stigmas finally come in contact with the projecting stamens and receive pollen from them, as is indicated in Fig. 257.

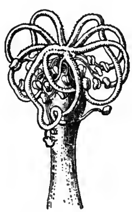


FIG. 257.—Stamens and Pistils of Round-Leafed Mallow. The stigmas curled round among the stamens to admit of self-pollination.

436. Movements of Floral Organs to aid in Pollination. — Besides the slow movements which the stamens and pistil make in such cases as those of the *Clerodendron* and the mallow, already described, the parts of the flower often admit of considerable and rather quick movements to assist the insect visitor to become dusted or smeared with pollen.

In some flowers whose stamens perform rapid movements when an insect enters, it is easy to see how directly

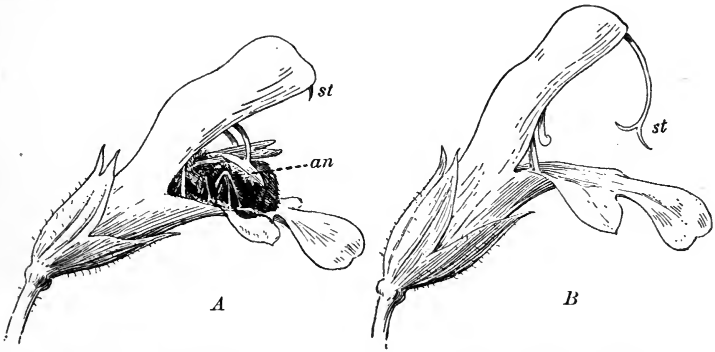
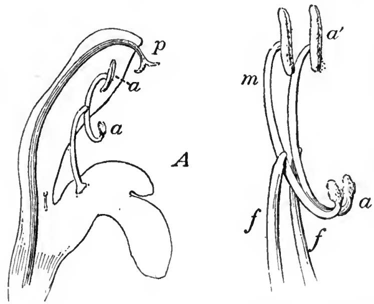


FIG. 258. — Two Flowers of Common Sage, one of them visited by a Bee.

useful the motion of the stamens is in securing cross-pollination. The stamens of the laurel, *Kalmia*, throw little masses of pollen, with a quick jerk, against the body of the visiting insect. Barberry stamens spring up against the visitor and dust him with pollen. The common garden sage matures its anthers earlier than its stigmas. In Fig. 258, *A*, the young flower is seen, visited by a bee, and one anther is shown pressed closely against the side of the bee's abdomen. The stigma, *st*, is hidden within the upper lip of the corolla. In *B*, an older flower, the anthers have withered and the stigma is now lowered so as to brush against the body of any bee which may enter. A little study of Fig. 259 will make clear the way in which the anthers are hinged, so that a bee striking the empty or barren anther-lobes, *a*, knocks the pollen-bearing lobes, *a′*, into a horizontal position, so that they will lie closely pressed against either side of its abdomen.



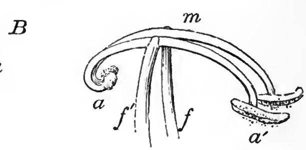
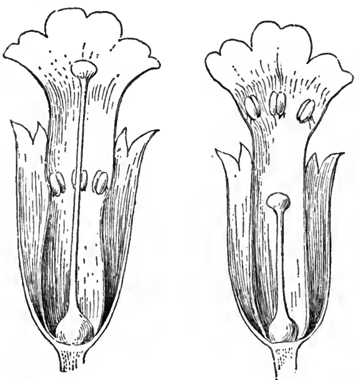


FIG. 259. — Flower and Stamens of Common Sage.

A, *p*, stigma; *a*, anthers; *B*, the two stamens in ordinary position; *f*, filaments; *m*, connective (joining anther-cells); *a′*, anther-cells; *C*, the anthers and connectives bent into a horizontal position by an insect pushing against *a*.

437. Flowers with Stamens and Pistils Each of Two Lengths. — The flowers of bluets, partridge-berry, the primroses, and a few other common plants secure cross-pollination by having essential organs of two forms (Fig. 260). Such flowers are said to be *dimorphous* (of two forms). In the short-styled flowers, II, the anthers are borne at the top of the corolla tube and the



I II

FIG. 260. — Dimorphous Flowers of the Primrose.

I, a long-styled flower; II, a short-styled one.

stigma stands about halfway up the tube. In the long-styled flowers, I, the stigma is at the top of the tube and the anthers are borne about halfway up. An insect pressing its head into the throat of the corolla of II would become dusted with pollen, which would be brushed off on the stigma of a flower like I. On leaving a long-styled flower the bee's tongue would be dusted over with pollen, some of which would necessarily be rubbed off on the stigma of the next short-styled flower that was visited. Cross-pollination is insured, since all the flowers on a plant are of one kind, either long-styled or short-styled, and since the pollen is of two sorts, each kind sterile on the stigma of any flower of similar form to that from which it came.

Trimorphous flowers, with long, medium, and short styles, are found in a species of loosestrife.[1]

438. Studies in Insect Pollination. — The student cannot gather more than a very imperfect knowledge of the details of cross-pollination in flowers without actually watching some of them as they grow, and observing their insect visitors. If the latter are caught and dropped into a wide-mouthed stoppered bottle containing a bit of cotton saturated with chloroform, they will be painlessly killed, and most of them may be identified by any one who is familiar with our common insects. The insects may be observed and classified in a general way into butterflies, moths, bees, flies, wasps, and beetles, without being captured or molested.

Whether these out-of-door studies are made or not, several flowers should be carefully examined and described as regards their arrangements for attracting and utilizing insect visitors (or birds). The following list includes a considerable number of the most accessible flowers of spring and early summer, about which it is easy to get information from books.

[1] See Miss Newell's *Reader in Botany*, Part II, pp. 60–63.

LIST OF INSECT-POLLINATED FLOWERS.[1]

I

1.	Flax	*Linum usitatissimum*	Müll.
2.	Missouri currant	*Ribes aureum*	Müll.
3.	Snowberry	*Symphoricarpus racemosus*	Müll.
4.	Lilac	*Syringa persica*	Müll.
5.	Periwinkle	*Vinca minor*	Müll.
6.	Mignonette	*Reseda odorata*	Müll.
7.	Pansy	*Viola tricolor*	Müll.
8.	Dead nettle	*Lamium album*	Lubbock.
9.	Bleeding heart	*Dicentra* (*Diclytra*) *spectabilis*	Müll.
10.	Columbine	*Aquilegia vulgaris*	Müll.
11.	Monkshood	*Aconitum Napellus*	Müll.

II

12.	Larkspur	*Delphinium elatum, D. consolida*	Müll.
13.	Herb Robert	*Geranium robertianum*	Müll.
14.	Pink	*Dianthus* (various species)	Müll.
15.	Fireweed	*Epilobium angustifolium*	Gray.
16.	Nasturtium	*Tropæolum majus*	Newell, Lubbock.
17.	Lily-of-the-valley	*Convallaria majalis*	Müll.
18.	Heal-all	*Brunella* (*Prunella*) *vulgaris*	Müll.
19.	Ground ivy	*Nepeta Glechoma*	Müll., Newell.
20.	Lousewort	*Pedicularis canadensis*	Müll., Newell.
21.	Snapdragon	*Antirrhinum majus*	Müll.
22.	Iris	*Iris versicolor*	Newell.
23.	Bellflower	*Campanula rapunculoides*	Müll.
24.	Horse-chestnut	*Æsculus Hippocastanum*	Newell.

[1] The plants in this list are arranged somewhat in the order of the complexity of their adaptations for insect pollination, the simplest first. It would be well for each student to take up the study of the arrangements for the utilization of insect visitors in several of the groups above, numbered with Roman numerals. The teacher will find explanations of the adaptations in the works cited by abbreviations at the right. Müll. stands for Müller's *Fertilization of Flowers;* Lubbock, for *British Wild Flowers, considered in Relation to Insects;* Gray, for Gray's *Structural Botany;* and Newell, for Miss Newell's *Outlines of Lessons in Botany*, Part II. Consult also Weed's *Ten New England Blossoms.*

III

25.	Yarrow	*Achillea millefolium*	Müll.
26.	Oxeye daisy	*Chrysanthemum Leucanthemum*	Müll.
27.	Dandelion	*Taraxacum officinale*	Müll., Newell.

IV

28.	Barberry	*Berberis vulgaris*	Lubbock.
29.	Mountain laurel	*Kalmia latifolia*	Gray.

V

30.	White clover	*Trifolium repens*	Müll.
31.	Red clover	*Trifolium pratense*	Müll.
32.	Locust	*Robinia Pseudacacia*	Gray.
33.	Wistaria	*Wistaria sinensis*	Gray.
34.	Vetch	*Vicia cracca*	Müll.
35.	Pea	*Pisum sativum*	Müll.
36.	Bean	*Phaseolus vulgaris*	Gray.
37.	Ground-nut	*Apios tuberosa*	Gray.

VI

38.	Partridge-berry	*Mitchella repens*	Gray.
39.	Primrose	*Primula grandiflora, P. officinalis*	Lubbock.
40.	Loosestrife	*Lythrum Salicaria*	Gray.

VII

41.	Milkweed	*Asclepias Cornuti*	Müll., Newell.

VIII

42.	Lady's-slipper	*Cypripedium acaule*	Newell.

439. Cleistogamous Flowers. — In marked contrast with such flowers as those discussed in the preceding sections, which bid for insect visitors or expose their pollen to be blown about by the wind, are certain flowers which remain closed even during the pollination of the stigma. These flowers are called cleistogamous and of course are not cross-pollinated. Usually they occur on plants which also bear flowers adapted for cross-pollination, and in this

Fig. 261. — A Violet, with Cleistogamous Flowers.

The objects which look like flower-buds are cleistogamous flowers in various stages of development. The pods are the fruit of similar flowers. The plant is represented as it appears in late July or August, after the ordinary flowers have disappeared.

case the closed flowers are much less conspicuous than the others, yet they produce much seed. Every one knows the ordinary flowers of the violet, but most people

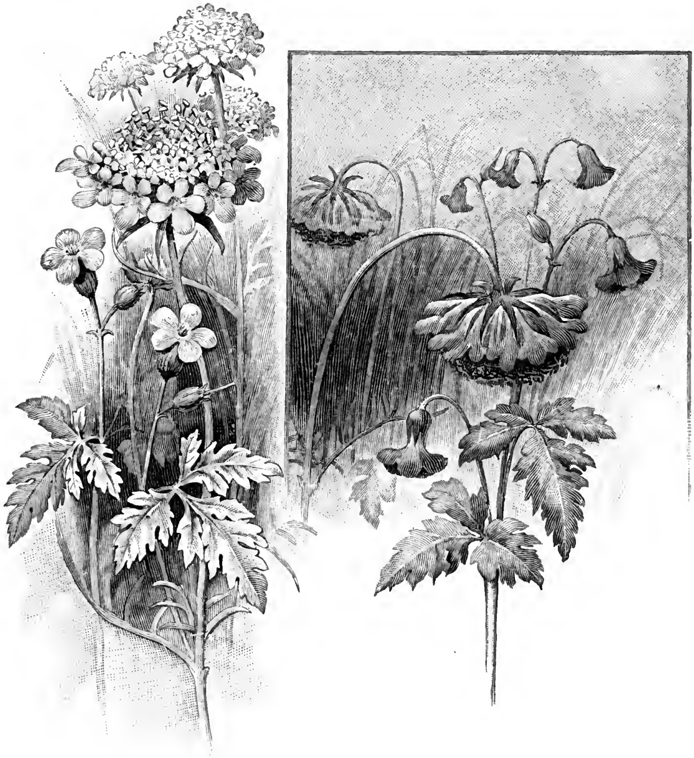


FIG. 262. — Protection of Pollen from Moisture.

At the left herb Robert and sweet scabious in sunny weather; at the right the same flowers during rain.

do not know that violets very generally, after the blossoming season (of their showy flowers) is over, produce many cleistogamous flowers, as shown in Fig. 261.

440. Protection of Pollen from Rain. — Pollen is very generally protected from being soaked and spoiled by rain or dew either by the natural position of the flower preventing rain from entering, as in the case with most gamopetalous, nodding flowers, or by changes in the position of the flower, and by its opening in sunny weather and closing at night or during rain. Sometimes the flower both changes its position and closes, as is the case with the herb Robert and the sweet scabious (Fig. 262). The adaptations of flowers to protect their pollen from becoming wet can best be understood by actually examining the same flower in sunshine and during rain.

Plate XI. — Aster and Golden-Rod

CHAPTER XXIX

HOW PLANTS ARE SCATTERED AND PROPAGATED

441. Means of Propagation among Cryptogams. — Some of the highest cryptogams, as the ferns, spread freely by means of their creeping rootstocks, and the gardener who wishes quickly to get large, strong ferns often finds it the easiest plan to cut to pieces and reset the rootstocks of a well-established plant. Some ferns also grow readily from bulblets produced on the fronds. In the walking fern the tip of the frond roots and begins a new plant. Most flowerless plants, however, are reproduced either by a process of fission, as in *Pleurococcus* (Sect. 278), *Diatoms* (Sect. 271), *Bacteria* (Sect. 266), and many other groups, or by some kind of spore (Sect. 259). The spore is usually so small an object that it is carried with the greatest ease by currents of water or of air, as the case may be, so that it is no sooner liberated than it is swept away, often to a very distant locality, where it can grow and not be interfered with by too many neighbors of its own kind. Thus spores of any of the marine algæ are certainly carried thousands of miles by ocean currents, and spores of tree ferns may be blown great distances from one oceanic island to another, or the spore contents of a puff-ball might travel on the wind half the breadth of a continent.

442. Dispersal of Seed-Plants by Roots and Rootstocks. — The student has learned (in Chapters IV and V) that roots and underground stems of many kinds may serve to reproduce the plant. Either roots or rootstocks may travel considerable distances horizontally in the course of their growth and then shoot up and produce a new plant, which later becomes independent of the parent. The sedges (Fig. 43) are excellent illustrations of this process, and trees like the common locust and the silver-leaf poplar become great nuisances in the neighborhood of lawns and gardens by sending up sprouts in many places. When growing wild, such trees as these depend largely upon spreading by the roots to keep up their numbers.[1]

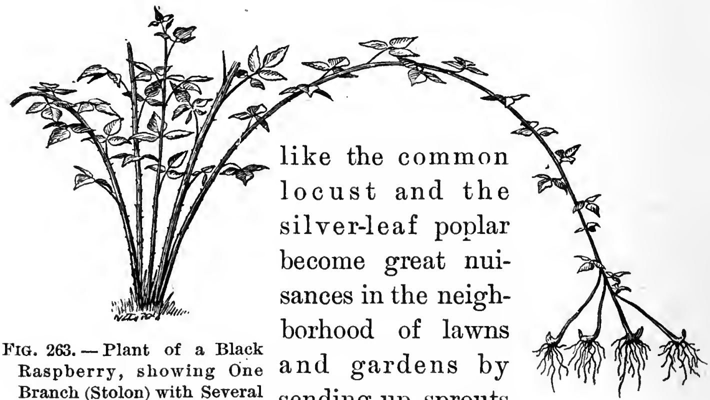


Fig. 263. — Plant of a Black Raspberry, showing One Branch (Stolon) with Several Tips rooting.

443. Dispersal of Seed-Plants by Branches. — There is a shrub of the Honeysuckle Family,[2] common in the northern woods, which is quite generally known as hobble-bush, or witch-hobble, and sometimes as trip-toe. This is because the branches take root at the end and so form loops which catch the foot of the passer-by. The same habit of growth is found in the raspberry-bush (Fig. 263), in one species of strawberry-bush (*Euonymus*), and some other shrubs. Many herbs like the strawberry-plant and the cinquefoil send

[1] See Beal's *Seed Dispersal*, Chapters II and III.
[2] *Viburnum lantanoides*.

out long, leafless runners which root at intervals and so propagate the plant, carrying the younger individuals off to a considerable distance from the parent plant.

Living branches may drop freely from the tree and then take root and grow, after having been blown or been carried by a brook or river to a favorable spot, perhaps hundreds of yards away. The so-called snap-willows lose many live twigs under conditions suitable for starting new trees.

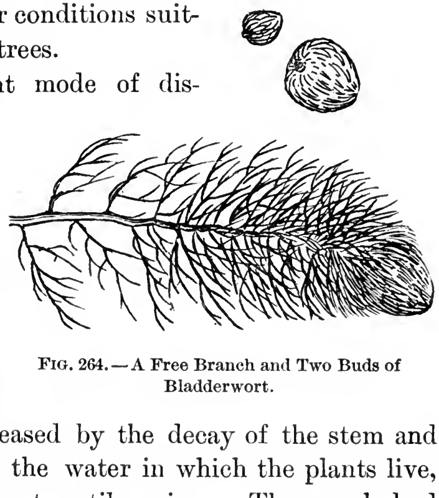


FIG. 264.—A Free Branch and Two Buds of Bladderwort.

A slightly different mode of dispersal from that of the raspberry is one in which buds separate from the plant and serve to propagate it. In the bladderwort (Fig. 264), at the close of the growing season, the terminal buds are released by the decay of the stem and sink to the bottom of the water in which the plants live, there to remain dormant until spring. Then each bud starts into life and gives rise to a new individual.

444. Dispersal of Seed-Plants by Bulblets. — Almost every farmer's boy knows what "onion-sets" are. These are little bulbs, produced at the top of a naked flower-stalk or scape by some kinds of onions which do not usually flower or bear seed. Tiger-lilies produce somewhat similar bulblets in the axils of the leaves, and there is a large number of species, scattered among numerous families of plants, all characterized by the habit of producing bulblets. When mature the bulblets fall off readily, and if they find lodgment on unoccupied soil, they grow readily into new plants. Sometimes they are carried moderate distances by wind or water, and if the ground slopes, they may easily roll far enough to get started in new places.

FIG. 265. — Fruit of Smoke-Tree (*Rhus Cotinus*).

Only one pedicel bears a fruit, all the others are sterile, branched, and covered with plumy hairs.

445. Dispersal of Seeds. — Seeds are not infrequently scattered by apparatus by which the plant throws them about. More commonly, however, they depend upon other agencies, such as wind, water, or animals, to carry them. Sometimes the transportation of seeds is due to the structure of the seeds themselves, sometimes to that of the fruit in which they are enclosed; the essential point is to have transportation to a long distance made as certain as possible, to avoid overcrowding.

446. Explosive Fruits. — Some dry fruits burst open when ripe in such a way as to throw their seeds violently about. Interesting studies may be made, in the proper season, of the fruits of the common blue violet, the pansy, the wild balsam, the garden balsam, the crane's-bill, the herb Robert, the witch-hazel, the Jersey tea, and some other common plants. The capsule of the tropical American sand-box tree bursts open when thoroughly dry with a noise like that of a pistol shot.

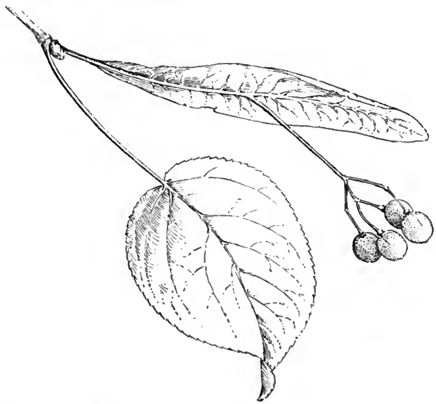


FIG. 266. — Fruits of Linden, with a Bract joined to the Peduncle and forming a Wing.

447. Winged or Tufted Fruits and Seeds. — The fruits of the ash, box-elder, elm, maple (Fig. 169), and many other trees, are provided with an expanded membranous wing. Some seeds, as those of the catalpa and the trumpet-creeper, are similarly appendaged. The fruits of the dandelion, the thistle (Fig. 267), the fleabane, and many other plants of the group to which these belong, and the seeds of the willow, the milkweed (Fig. 267), the willow-herb, and other plants, bear a tuft of hairs.

The student should be able, from his own observations on the falling fruits of some of the trees and other plants above mentioned, to answer such questions as the following:

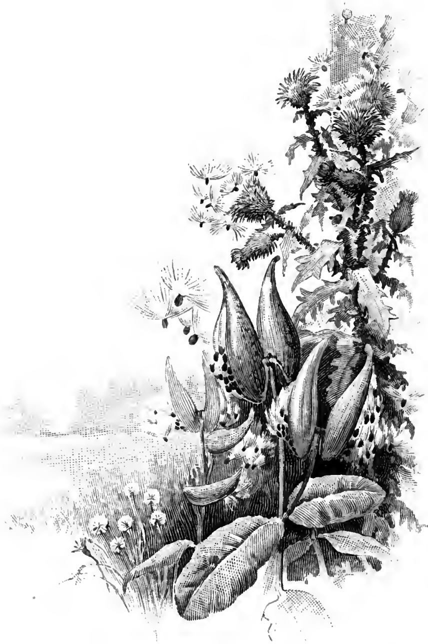


FIG. 267. — Winged Fruits of Thistle; Winged Seeds of Milkweed.

What is the use of the wing-like appendages? of the tufts of hairs?

Which set of contrivances seems to be the more successful of the two in securing this object?

What particular plant of the ones available for study seems to have attained this object most perfectly?

What is one reason why many plants with tufted fruits, such as the thistle and the dandelion, are extremely troublesome weeds?

A few simple experiments, easily devised by the student, may help him to find answers to the questions above given.[1]

448. Tumbleweeds. — Late in the autumn, fences, particularly on prairie farms that are not carefully tilled, often serve as lodging-places for immense numbers of certain dried-up plants known as tumbleweeds. These blow about over the level surface until the first snow falls and

[1] See Kerner and Oliver, Vol. II, pp. 833–875; also Beal's *Seed Dispersal*.

even after that (Fig. 269), often traveling for many miles before they come to a stop, and rattling out seeds as they go. Some of the commonest tumbleweeds are the Russian thistle (Fig. 268), the pigweed (*Amarantus albus*, Fig. 269), the tickle-grass (Fig. 270), and a familiar pepper-grass (*Lepidium*). In order to make a successful tumbleweed, a plant must be pretty nearly globular in form when fully grown and dried, must be tough and light, must break off near the ground, and drop its seeds only a few at a time as it travels. A single plant of Russian thistle is sometimes as much as three feet high and six feet in diameter and carries not less than two hundred thousand seeds.

FIG. 268. — Russian Thistle.

449. Many-Seeded Pods with Small Openings. — There are many fruits which act somewhat like pepper-boxes. The capsule of the poppy is a good instance of this kind, and the fruit of lily, monkshood (Fig. 168), columbine, larkspur, and jimson weed (Fig. 271) acts in much the same way. Clamping the dry peduncle of any one of these ripe fruits, so as to hold it upright above the table-top, and then swinging it back and forth, will readily show its efficiency in seed dispersal.

450. Study of Transportation by Water. — Nothing less than a long series of observations by the pond-margin and the brookside will suffice to show how general and important is the work done by water in carrying the seeds of aquatics. An experiment will, however, throw some light on the subject.

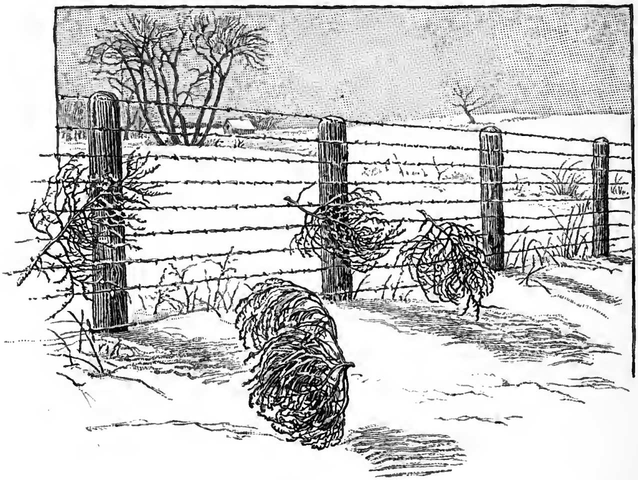


FIG. 269. — Tumbleweeds[1] lodged against a Wire Fence in Winter.

EXPERIMENT XL

Adaptation for Transportation by Water. — Collect fruits of as many aquatic, semi-aquatic, or riverside and brookside species of plants as possible, place them on shallow pans of water and notice what proportion of all the kinds studied will float. Leave them twenty-four hours or more and see whether all the kinds that floated at first are still afloat. Some desirable fruits for this experiment

[1] *Amarantus albus.*

are: aquatic grasses, rushes and sedges, polygonums, water-dock, bur-reed, arrowhead, water-plantain, pickerel-weed, alder, button-bush, water-parsnip (*Sium*), water-hemlock (*Cicuta*), water penny-wort (*Hydrocotyle*).

451. Distances traversed by Floating Seeds. — Ocean currents furnish transportation for the longest journeys that are made by floating seeds. It is a well-known fact that cocoa-palms are among the first plants to spring up on newly formed coral islands. The nuts from which these palms grew may readily have floated a thousand miles or more without injury. On examining a cocoanut with the fibrous husk attached, just as it fell from the tree, it is easy to see how well this fruit is adapted for transportation by water. There are altogether about a hundred drifting fruits known, one (the Maldive nut) reaching a weight of twenty to twenty-five pounds.

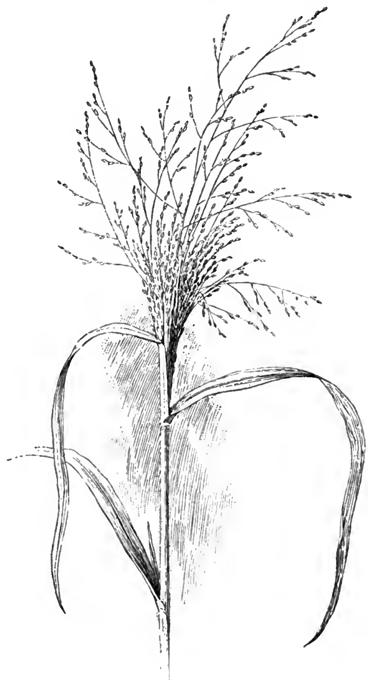


FIG. 270. — Panicle of Tickle-Grass, a Common Tumbleweed.

452. Burs. — A large class of fruits is characterized by the presence of hooks on the outer surface. These are sometimes outgrowths from the ovary, sometimes from the calyx, sometimes from an involucre. Their office is to attach the fruit to the hair or fur of passing animals. Often, as in sticktights (Fig. 272), the hooks are comparatively weak, but in other cases, as in the cocklebur (Fig. 272), and still more in the Martynia, the fruit of which in the green condition is much used for pickles, the hooks are exceedingly strong. Cockleburs can hardly be removed from the tails of horses and cattle, into which

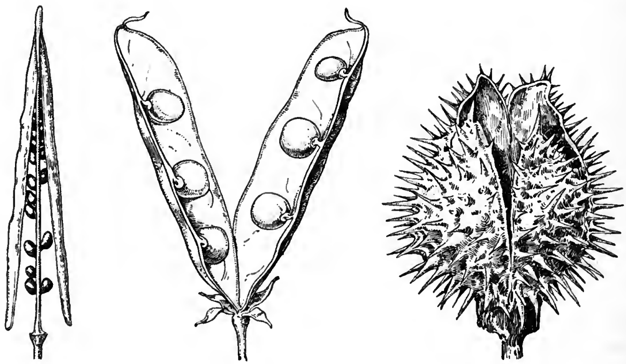


Fig. 271. — Three Fruits adapted for Dispersal by the Shaking Action of the Wind. I, celandine; II, pea; III, jimson weed (*Datura*).

they have become matted, without cutting out all the hairs to which they are fastened.

A curious case of distribution of this kind occurred in the island of Ternate, in the Malay Archipelago. A buffalo with his hair stuck full of the needle-like fruits of a grass[1] was sent as a present to the so-called King of Ternate. Scattered from the hair of this single animal, the grass soon spread over the whole island.

[1] *Andropogon acicularis*.

Why do bur-bearing plants often carry their fruit until late winter or early spring?

What reason can be given for the fact that the burdock, the cocklebur, the beggar's-ticks, the hound's-tongue, and many other common burs, are among the most persistent of weeds?

453. Uses of Stone Fruits and of Fleshy Fruits to the Plant. — Besides the *dry fruits*, of which some of the principal kinds have been mentioned, there are many kinds

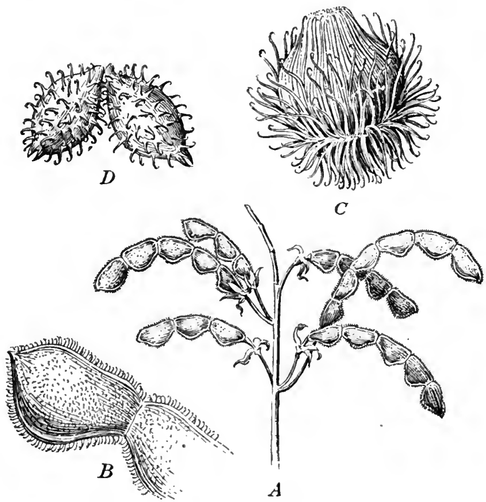
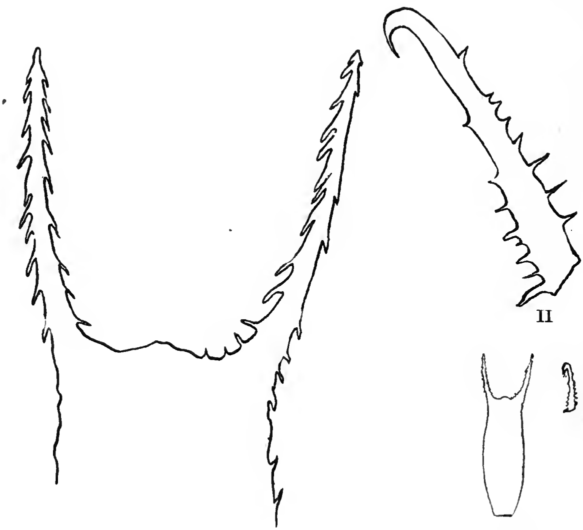


FIG. 272. — Burs.

A, sticktights ; *B*, sticktights, two segments, magnified ; *C*, burdock ; *D*, cockleburs.

of *stone fruits and other fleshy fruits* (Sects. 242–247). Of these the great majority are eatable by man or some of the lower animals, and oftentimes the amount of sugar and other food material which they contain is very considerable. It is a well-recognized principle of botany, and of zoölogy as well, that plants and animals do not make unrewarded outlays for the benefit of other species. Evidently the pulp of fruits is not to be consumed or used



I III IV

FIG. 273. — Barbs and Hooks of Burs.

I, barbed points from fruit of beggar's-ticks, magnified eleven times; II, hook of cocklebur, magnified eleven times; III, beggar's-ticks fruit, natural size; IV, cocklebur hook, natural size.

as food by the plant itself or (in general) by its seeds. It is worth while, therefore, for the student to ask himself some such questions as these:[1]

(1) Why is the pulp of so many fruits eatable?

(2) Why are the seeds of many pulpy fruits bitter or otherwise unpleasantly flavored, as in the orange?

(3) Why are the seeds or the layers surrounding the

[1] See Kerner and Oliver's *Natural History of Plants*, Vol. II, pp. 442–450.

seeds of many pulpy fruits too hard to be chewed, or digested, as in the date and the peach?

(4) Why are the seeds of some pulpy fruits too small to be easily chewed, and also indigestible, as in the fig and the currant?

(5) Account for the not infrequent presence of currant bushes or asparagus plants in such localities as the forks of large trees, sometimes at a height of twenty, thirty, or more feet above the ground (Fig. 274).

Careful observation of the neighborhood of peach, plum, cherry, or apple trees at the season when the fruit is ripe and again during the following spring, and an examination into the distribution of wild apple or pear trees in pastures where they occur, will help the student who can make such observations to answer the preceding questions. So, too, would an examination of the habits of fruit-eating quadrupeds and of the crop and gizzard of fruit-eating birds during the season when the fruits upon which they feed are ripe.

FIG. 274. — Red Raspberry Bush, in Fork of a Maple.

454. Seed-Carrying purposely done by Animals. — In the cases referred to in the preceding sections, animals have been seen to act as unconscious or even unwilling seed-carriers. Sometimes, however, they carry off seeds with the plan of storing them for food. Ants drag away with them to their nests certain seeds which have fleshy growths on their outer surfaces. Afterwards they eat these fleshy

FIG. 275. — Red Cedar Trees planted by Birds roosting on Fences.

parts at their leisure, leaving the seed perfectly fit to grow, as it often does.[1]

Squirrels and bluejays are known to carry nuts and acorns about and bury them for future use. These

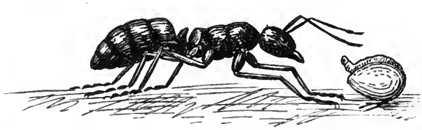


FIG. 276. — Seed of Bloodroot with Caruncle or Crest, which serves as a Handle for Ants to hold on to. Ant ready to take the seed.

deposits are often forgotten and so get a chance to grow, and in this way a good deal of tree-planting is done.

[1] See Beal's *Seed Dispersal*, pp. 69, 70.

CHAPTER XXX

THE STRUGGLE FOR EXISTENCE AND THE SURVIVAL OF THE FITTEST[1]

455. Weeds. — Any flowering plant which is troublesome to the farmer or gardener is commonly known as a weed. Though such plants are so annoying from their tendency to crowd out others useful to man, they are of extreme interest to the botanist on account of this very hardiness. The principal characteristics of the most successful weeds are their ability to live in a variety of soils and exposures, their rapid growth, resistance to frost, drought, and dust, their unfitness for the food of most of the larger animals, in many cases their capacity to accomplish self-pollination, in default of cross-pollination, and their ability to produce many seeds and to secure their wide dispersal. Not every weed combines all of these characteristics. For instance, the velvet-leaf or butter-print,[2] common in cornfields, is very easily destroyed by frost; the pigweed and purslane are greedily eaten by pigs, and the ragweed by some horses. The horse-radish does not usually produce any seeds.

It is a curious fact that many plants which have finally proved to be noxious weeds have been purposely introduced into the country. The fuller's teasel, melilot, horse-radish, wild carrot, wild parsnip, tansy, oxeye daisy,

[1] See Darwin's *Origin of Species*, Chapters III and IV.

[2] *Abutilon Avicennæ.*

and field-garlic are only a few of the many examples of very troublesome weeds which were at first planted for use or for ornament.

456. Study of Weeds. — Select two or more out of the following list of weeds and report on the qualities which make them troublesome from the farmer's point of view (successful from their own).[1]

LIST OF WEEDS[2]

1. Barn-grass,* *Panicum Crus-galli.*
2. Beggar's lice,* *Cynoglossum officinale.*
3. Beggar's-ticks, *Bidens frondosa.*
4. Black mustard,* *Brassica nigra.*
5. Blue thistle,* *Echium vulgare.*
6. Buffalo bur, *Solanum rostratum.*
7. Burdock,* *Arctium Lappa.*
8. Buttercup,* *Ranunculus bulbosus.*
9. Butterweed,* *Erigeron canadensis.*
10. Carpet weed, *Mollugo verticillata.*
11. Charlock,* *Brassica Sinapistrum.*
12. Chess or cheat,* *Bromus secalinus.*
13. Chickweed, *Stellaria media.*
14. Chicory,* *Cichorium Intybus.*
15. Clover dodder,* *Cuscuta Trifolii.*
16. Cocklebur,* *Xanthium spinosum.*
17. Corn cockle,* *Agrostemma Githago.*

[1] This study will be of little value in city schools, since the plants should be examined as they grow. Specimens of the mature weed and of its fruits and seeds may be preserved by the teacher from one season to another for class use. Whole specimens of small plants, such as purslane, may be put into preservative fluid (see Handbook). Ordinary weeds, such as ragweed, pigweed, etc., may be pressed and kept as roughly prepared herbarium specimens, while such very large plants as jimson weed, dock, etc., may be hung up by the roots and thus dried.

[2] Names marked in the list thus * are those of plants introduced from other countries, mostly from Europe.

18. Cow herb,* *Saponaria Vaccaria.*
19. Daisy, oxeye,* *Chrysanthemum Leucanthemum.*
20. Dandelion,* *Taraxacum officinale.*
21. Dock, *Rumex crispus.*
22. Dog fennel,* *Anthemis cotula.*
23. Fox-tail grass,* *Setaria glauca.*
24. Horse-nettle, *Solanum carolinense.*
25. Jamestown weed or Jimson weed,* *Datura Stramonium* or *D. Tatula.*
26. Johnson grass, *Andropogon halepensis.*
27. Mallow,* *Malva rotundifolia.*
28. Milkweed, *Asclepias Cornuti.*
29. Nettle, *Urtica gracilis.*
30. Pigweed,* *Amarantus retroflexus.*
31. Pigweed,* *Chenopodium album.*
32. Plantain,* *Plantago major.*
33. Pokeberry, *Phytolacca decandra.*
34. Purslane, *Portulaca oleracea.*
35. Quick-grass,* Witchgrass, *Agropyrum repens.*
36. Ragweed, *Ambrosia artemisiæfolia.*
37. Rib grass,* *Plantago lanceolata.*
38. Sand bur, *Cenchrus tribuloides.*
39. Shepherd's purse,* *Capsella Bursa-pastoris.*
40. Smartweed, *Polygonum Hydropiper.*
41. Sorrel,* *Rumex Acetosella.*
42. Spanish needles, *Bidens bipinnata.*
43. Sticktights, *Desmodium canadense.*
44. Thistle,* *Cirsium lanceolatum, C. arvense.*
45. Yarrow, *Achillea Millefolium.*

457. Origin of Weeds.[1] — By far the larger proportion of our weeds are not native to this country. Some have been brought from South America and from Asia, but most of the *introduced* kinds come from Europe. The importation of various kinds of grain and of garden-seeds,

[1] See the article "Pertinacity and Predominance of Weeds," in *Scientific Papers of Asa Gray*, selected by C. S. Sargent, Vol. II, pp. 234–242.

mixed with seeds of European weeds, will account for the presence of many of the latter among us. Others have been brought over in the ballast of vessels. Once landed, European weeds have succeeded in establishing themselves in so many cases, because they were superior in vitality and in their power of reproduction to our native plants. This may not improbably be due to the fact that the European and western Asiatic vegetation, much of it consisting from very early times of plants growing in comparatively treeless plains, has for ages been habituated to flourish in cultivated ground and to contend with the crops which are tilled there.

458. Plant Life maintained under Difficulties. — Plants usually have to encounter many obstacles even to their bare existence. For every plant which succeeds in reaching maturity and producing a crop of spores or of seeds there are hundreds or thousands of failures, as it is easy to show by calculation. The morning-glory (*Ipomœa purpurea*) is only a moderately prolific plant, producing, in an ordinary soil, somewhat more than three thousand seeds.[1] If all these seeds were planted and grew, there would be three thousand plants the second summer, sprung from the single parent plant. Suppose each of these plants to bear as the parent did, and so on. Then there would be :

9,000,000 plants the third year.
27,000,000,000 plants the fourth year.
81,000,000,000,000 plants the fifth year.
243,000,000,000,000,000 plants the sixth year.
729,000,000,000,000,000,000 plants the seventh year.

[1] Rather more than three thousand two hundred by actual count and estimation.

It is not difficult to see that the offspring of a single morning-glory plant would, at this rate, soon actually cover the entire surface of the earth. The fact that morning-glories do not occupy any larger amount of territory than they do must therefore depend upon the fact that the immense majority of their seeds are not allowed to grow into mature plants.

There are many plants which would yield far more surprising results in a calculation similar to that just given than are afforded by the morning-glory. For instance, a foxglove capsule contains on an average nearly 1800 seeds. A small foxglove plant bears from 140 to 200 capsules and a large one from 530 to 700. Therefore a single plant may produce over 1,250,000 seeds. A single orchid plant[1] has been shown to produce over 10,000,000 seeds.

459. Importance of Dispersal of Seeds. — It is clear that any means of securing the wide distribution of seeds is of vital importance in continuing and increasing the numbers of any kind of plant, since in this way destruction by overcrowding and starvation will be lessened.

A few of the means of transportation of seeds have been described in Sects. 445–454, but the cases are so numerous and varied that a special treatise might well be devoted to this subject alone.

460. Destruction of Plants by Unfavorable Climates. — Land-plants, throughout the greater part of the earth's surface, are killed in enormous numbers by excessive heat and drought, by floods, or by frost. After a very dry spring or summer the scantiness of the crops, before the era of railroads which nowadays enable food to be brought

[1] *Maxillaria*, see Darwin's *Fertilization of Orchids*, Chapter IX.

in rapidly from other regions, often produced actual famine. Wild plants are not observed so carefully as cultivated ones are, but almost every one has noticed the patches of grass, apparently dead, in pastures and the withered herbaceous plants everywhere through the fields and woods after a long drought.

Floods destroy the plants over large areas, by drowning them, by sweeping them bodily away, or by covering them with sand and gravel.

Frosts kill many annual plants before they have ripened their seeds, and severe and changeable winters sometimes kill perennial plants.

461. Destruction by Other Plants. — Overcrowding is one of the commonest ways in which plants get rid of their weaker neighbors. If the market-gardener sows his lettuce or his beets too thickly, few perfect plants will be produced, and the same kind of effect is brought about in nature on an immense scale. Sometimes plants are overshadowed and stunted or killed by the growth all about them of others of the same kind; sometimes it is plants of other kinds that crowd less hardy ones out of existence.

Whole tribes of parasitic plants, some comparatively large, like the dodder and the mistletoe, others microscopic, like blights and mildews, prey during their whole lives upon other plants.

462. Adaptations to meet Adverse Conditions. — Since there are so many kinds of difficulties to be met before the seed can grow into a mature plant and produce seed in its turn, and since the earth's surface offers such extreme variations as regards heat, sunlight, rainfall, and quality of soil, it is evident that there is a great opportunity offered for competition among plants. Of several plants of the same kind, growing side by side, where there is room for but one full-grown one, all may be stunted, or one may develop more rapidly than the others, starve them out, and shade them to death. Of two plants of different kinds the hardier will crowd out the less hardy, as ragweed, pigweed, and purslane do with ordinary garden crops. Weeds like these are rapid growers, stand drought or shade well, will bear to be trampled on, and, in general, show remarkable toughness of organization.

Plants which can live under conditions that would be fatal to most others will find much less competition than the rank and file of plants are forced to encounter. Lichens, growing on barren rocks, are thus situated, and so are the fresh-water plants, somewhat like pond-scum in their structure, which are found growing in hot springs at temperatures of 140°, or in some cases nearly up to 200°.

463. Examples of Rapid Increase. — Nothing but the opposition which plants encounter from overcrowding or from the attacks of their enemies prevents any hardy kind of plant from covering all suitable portions of a whole continent, to the exclusion of most other vegetable life. New Zealand and the pampas of La Plata and Paraguay, in South America, have, during the present century, furnished wonderful examples of the spread of European species of plants over hundreds of thousands of square miles of territory. The newcomers were more vigorous, or in some way better adapted to get on in the world than the native plants which they encountered, and so managed to crowd multitudes of the latter out of existence.

In our own country a noteworthy case of the kind has occurred so very recently that it is of especial interest to American botanists. The so-called Russian thistle (Fig. 268), which is merely a variety of the saltwort, so common along the Atlantic coast, was first introduced into South Dakota in flaxseed brought from Russia and planted in 1873 or 1874. In twenty years from that time the plant had become one of the most formidable weeds known, over an area of about twenty-five thousand square miles.

464. Importance of Adaptiveness in Plants. — It may be inferred from the preceding sections that a premium is set on all changes in structure or habits which may enable plants to resist their living enemies or to live amid partially adverse surroundings of soil or climate. It would take a volume to state, even in a very simple way, the conclusions which naturalists have drawn from this fact of a savage competition going on among living things, and it will be enough to say here that *the existing kinds of plants to a great degree owe their structure and habits to the operation of the struggle for existence*, this term including *the effort to respond to changes in the conditions by which they are surrounded.* How the struggle for existence has brought about such far-reaching results will be briefly indicated in the next section.

465. Survival of the Fittest. — When frost, drought, blights, or other agencies kill most of the plants in any portion of the country, it is often the case that many of the plants which escape do so because they can stand more hardship than the ones which die. In this way delicate individuals are weeded out and those which are more robust survive. But other qualities besides mere toughness often decide which plant or plants of any particular kind shall live and which ones shall die out. In every grove of oaks there are some with sweeter and others with more bitter acorns. One shellbark hickory bears nuts whose shell is easily cracked by hogs, while another protects its seeds by a shell so hard that it is cracked only by a pretty heavy blow. In case of all such differences, there is a strong tendency to have the less eatable fruit or seed preserved and allowed to grow, while the more eatable varieties will be destroyed. Some individuals of the European holly produce bright red berries, while others produce comparatively inconspicuous yellow ones. It has been found that the red berries are much more promptly carried off by birds, and the seeds therefore much more widely distributed than the yellow ones are. The result of this kind of advantage, in any of its countless forms, is sometimes called *survival of the fittest*, and sometimes *natural selection.* The latter name means only that the outcome of the process just described, as it goes on in nature, is much the same as that of the gardener's selection, when, by picking out year by year the earliest ripening peas or certain kinds of the oddest-colored chrysanthemums, he obtains permanent new varieties. Natural agencies, acting on an enormous scale through many ages, may well be supposed to have brought about the perpetuation of millions of such variations as are known to be of constant occurrence among plants, wild as well as cultivated.

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BERGEN'S BOTANY

KEY AND FLORA

PACIFIC COAST EDITION

PREPARED BY

ALICE EASTWOOD

OF THE CALIFORNIA ACADEMY OF SCIENCES, AUTHOR OF THE FLORA IN THE ROCKY MOUNTAIN EDITION

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PREFACE

This Flora of the Pacific States has been made to enable pupils to obtain a clear idea of the method of classifying plants through practical experience in identifying the most common genera and species of the coast. It is to serve as a guide in understanding the characteristics and relationships of large and important orders and genera, and, to some extent, in identifying species.

The species included have been those most widely distributed or those most abundant near large centers of population, so that sufficient material might easily be obtained for class study. Species not clearly and easily defined have been omitted even when abundant, so as to render the possibility of error as little as possible. Where a difference of opinion exists among botanists in regard to generic names, both have generally been given, one in parentheses.

Teachers will find, in whatever part of the Pacific States they may be, that they can collect a sufficient number of the plants here included to afford their pupils all the drill necessary. It is advised that the teachers furnish the plants for class study, being careful to select only from those here included rather than to allow the pupils themselves to select at random from the flora of the neighborhood; otherwise, the pupil is likely to become discouraged by failure in identifying plants not described in the book.

Teachers who are in doubt about any plants are earnestly requested to send specimens to the Academy of Sciences, San Francisco, where they will be compared with herbarium specimens and identified. The specimens should have both flower and fruit when possible, and in the case of herbs the entire plant should be sent, root and all.

It requires quite a library of botanical books to identify Pacific Coast species, since there is no book published that contains even all the known species, and there are many species still undiscovered. It is neither possible nor desirable to attempt to include all in a school flora. The chief books needed for a more complete study are the two large and expensive volumes of the State Geological Survey; the following botanical works of Prof. E. L. Greene: *Pittonia*, *Flora Franciscana*, and *The Botany of the Bay Region*; *Western Cone-bearers*, by J. G. Lemmon; and, for *Compositæ* and *Gamopetalæ*, Gray's *Synoptical Flora*.

The plan of arrangement in preparing this Flora has been that of Professor Bergen's *Key and Flora to the Spring-blooming Plants of the Northern and Middle States*, which replaces this in the Eastern edition of his book. It seemed that a plan which he had tried and found successful was better to adopt than one that was new and untried. Whenever possible, his descriptions have been used, the aim throughout having been to follow as he led.

The botany of the Geological Survey, Professor Greene's botanical works, and Dr. Behr's *Botany of the Vicinity of San Francisco* have all been used in compiling the descriptions and making the Key.

The figures referred to are to be found in the text of this Key, unless the reference is preceded by *f.* or *e.* The former refers to Bergen's *Foundations of Botany*, the latter to his *Elements of Botany*.

The pronunciation is indicated by accent marks and the division of the accented syllable. A vowel ending this syllable has a long sound; but when the accented syllable ends in a consonant, the vowel has a short sound. It matters little whether the English or Continental sounds for the vowels are used; the former are more generally authorized, though the latter are becoming more and more prevalent.

In this revised edition I am indebted to Prof. C. V. Piper, of the Agricultural College, at Pullman, Washington, for additions to the Flora from Washington and Oregon, and to Mr. Louis A. Greata, of Los Angeles, for additions from the country adjacent to Los Angeles.

ALICE EASTWOOD

ACADEMY OF SCIENCES
SAN FRANCISCO

KEY TO SOME FAMILIES OF PHANEROGAMS

GYMNOSPERMS. Ovules not enclosed in an ovary.

Trees or shrubs, usually with needle-shaped or scale-like evergreen leaves and monœcious or diœcious flowers in catkins, the pistillate ones usually ripening into cones . . . . (Coniferæ), Pine Family, p. 13

ANGIOSPERMS. Ovules in an ovary.

MONOCOTYLEDONS. Flowers generally on plan of 3, never of 5; leaves usually parallel-veined.

GLUMACEOUS DIVISION. Flowers rudimentary, enclosed in husk-like bracts.

Bracts for each flower 2; stems jointed, hollow, cylindrical or nearly so . . . . (Gramineæ), Grass Family, p. 21

Bracts for each flower 1; stems not jointed, solid, triangular (Cyperaceæ), Sedge Family, p. 22

PETALOIDEOUS DIVISION. Flowers having a true perianth; not on a spadix.

Ovary free from the perianth, Stamens 6 (Liliaceæ), Lily Family, p. 23

Ovary adnate to the perianth.

Stamens 6 . (Amaryllidaceæ), Century Plant Family, p. 36

Stamens 3 . . . . (Iridaceæ), Iris Family, p. 37

Stamens 1 or (rarely) 2 . . (Orchidaceæ), Orchis Family, p. 39

DICOTYLEDONS. Flowers generally on the plan of 4 or 5. In woody plants the woody fiber forms concentric rings.

DIVISION I. APETALÆ. With but one set of floral envelopes or none.

Flowers in catkins. Trees or shrubs.

Diœcious, 1 flower to each scale of the catkin; fruit a many-seeded pod, each seed furnished with a tuft of cotton (Salicaceæ), Willow Family, p. 40

Monœcious; sterile catkins drooping; fertile, erect, cone-like, with 1 or 2 flowers under each stiff, shield-shaped scale (Betulaceæ), Alder Family, p. 42

Monœcious, androgynous; catkins short, erect, with 1 flower under each scale of the fertile catkin; fruit a round nutlet
(Myricaceæ), Wax-myrtle Family, p. 40

Monœcious, sterile flowers only in catkins; fruit a nut in a cup or bur, or a leaf-like cylindrical sheath
(Cupuliferæ), Oak Family, p. 44

Diœcious, sterile flowers with calyx 4-parted, stamens 4; fertile flowers with calyx 2-lobed or wanting, ovary 1-celled, 2-ovuled, styles 2; fruit a berry (Garryaceæ), Silk-tassel Bush Family, p. 120

Flowers not in catkins.

Ovary inferior,

6-celled, perianth regular and 3-lobed or irregular, stamens 6–12
(Aristolochiaceæ), Dutchman's Pipe Family, p. 46

1-celled, sunk in the axis of the conical spike, which has numerous flowers, and a persistent petal-like involucre; flowers naked, of 6–8 stamens and 3–6 pistils, each subtended by a white bract. Aromatic herbs of wet alkaline places
(Houttuynia), Yerba Mansa, p. 40

Ovary superior,

3-celled, 3-ovuled, stigmas 3–6. Monœcious or diœcious. Staminate flowers with 1 to many stamens. Plants with milky juice
(Euphorbiaceæ), Spurge Family, p. 99

1-celled, forming a 3-sided akene, stamens 9, perianth of 6 divisions usually colored like a corolla
(Polygonaceæ), Buckwheat Family, p. 47

1-celled, forming a flat akene with embryo coiled, stamens 5 opposite the divisions of the green perianth; plants often fleshy and covered with scurf . . (Chenopodiaceæ), Pigweed Family, p. 49

Similar to *Chenopodiaceæ*, but the divisions of the perianth are papery and persistent with similar bracts
(Amarantaceæ), Amaranth Family, p. 51

1-celled, 1-seeded, calyx corolla-like, monosepalous, the persistent herbaceous base hardening around the akene, style 1; flowers in calyx-like involucres
(Nyctaginaceæ), Four-o'clock Family, p. 51

Stamens 9 in 3 rows, anthers 4-celled, opening by uplifted valves; sepals 6, petaloid, pistil simple; flowers in umbels; trees with aromatic foliage . . . (Lauraceæ), Laurel Family, p. 63

DIVISION II. POLYPETALÆ. Petals distinct (in some genera wanting).

Stamens hypogynous (on the receptacle below the superior ovary).

Stamens Numerous

Separate, and the other floral organs distinct, petals sometimes wanting, flowers with the sepals 5 or irregular
(Ranunculaceæ), Buttercup Family, p. 58

Separate, flowers regular, sepals (generally 2) half as many as the petals and falling as the petals expand
(Papaveraceæ), Poppy Family, p. 64

Monadelphous, attached to the bases of the petals.

Anthers 1-celled, kidney-shaped
(Malvaceæ), Mallow Family, p. 105

Anthers 2-celled, petals wanting, sepals petal-like
(Fremontia), p. 107

United into 3–5 bunches, sepals and petals 5, leaves opposite, punctate
(Hypericaceæ), St. John's-wort Family, p. 107

About 20, sepals 5 (2 scale-like), petals 5, soon falling
(Cistaceæ), Rockrose Family, p. 108

Stamens 10 or less

10 (rarely fewer), petals 5 (sometimes wanting), capsule splitting into twice as many valves as styles. Seeds on axillary placenta
(Caryophyllaceæ), Pink Family, p. 55

10 or 5, sepals and petals 5, carpels 5 on a spike-like axis, distinct at base but cohering by their stigmas and separating from the axis at the base first, 1-seeded . . . . (Geraniaceæ), p. 95

10, sepals and petals 5, carpels distinct, 1-seeded, globose, at the base of a common style; juice pungent . . . (Limnanthes), p. 97

10, sepals and petals 5, carpels united into a 5-celled ovary with 5 styles; leaves compound with 3 leaflets; juice acid . . (Oxalis), p. 97

10 or 5, equal to or double the number of petals; herbs with fleshy leaves . . . . (Crassulaceæ), Stonecrop Family, p. 74

6 or 9, anthers 2-celled, opening by uplifted valves (*f.* Fig. 160, II; *e.* Fig. 138, II); bracts, sepals, petals, and stamens opposite each other; pistil simple (Berberidaceæ), Barberry Family, p. 62

6 (4 long and 2 short), petals and sepals 4 (petals sometimes wanting); fruit 2-celled with a papery partition, or sometimes 1-celled and indehiscent; herbs with pungent juice
(Cruciferæ), Mustard Family, p. 67

6, or sometimes more, nearly equal, sepals and petals 4; pod 1-celled, on a long slender stalk (Capparidaceæ), Caper Family, p. 73

6, united by the filaments to form 2 equal sets; flowers irregular
(Fumariaceæ), Bleeding Heart Family, p. 66

5, sometimes united over the pistil; petals 5, one of them with a spur
(Violaceæ), Violet Family, p. 109

1 to many, sepals 2–8, petals 5–16, styles 3–8-cleft, ovary 1-celled with placenta axillary; plants with fleshy leaves and mostly showy flowers that open only in bright sunshine
(Portulacaceæ), Portulaca Family, p. 52

Stamens 4–7, petals 4–5 with long claws, ovary 1-celled, with as many parietal placentæ as divisions of the style
(Frankeniaceæ), Yerba Reuma Family, p. 108

6–8, the filaments united into a split sheath; flowers irregular, superficially resembling the *Papilionaceæ*, sepals 5, petals 2; pod 2-celled, flattened contrary to the partition
(Polygalaceæ), Polygala Family, p. 98

5, monadelphous at base, petals soon falling, capsule splitting into twice as many divisions as stigmas
(Linaceæ), Flax Family, p. 98

2 (rarely 3 or 4), petals 4, 2, or wanting, calyx 4-toothed; fruit winged from the summit, 1-seeded; polygamous or diœcious trees or shrubs with opposite compound leaves . . (Fraxinus), Ash, p. 128

Ovary superior or nearly so.

Stamens distinctly on the calyx or on a disk simulating a calyx tube

Numerous; ovary simple or compound, free from or partly united to the disk; leaves alternate, with stipules that sometimes fall early; seeds without endosperm (Rosaceæ), Rose Family, p. 80

Stamens indefinite, petals merging into the sepals, carpels numerous, becoming akenes within a hollow disk; aromatic shrubs, having opposite leaves and no stipules
(Calycanthaceæ), Sweet Shrub Family, p. 80

Variable in number (5, 10, 20), carpels 2–5, completely or partially united to the calyx, styles distinct; leaves without stipules; seed with endosperm (Saxifragaceæ), Saxifrage Family, p. 75

10, distinct, monadelphous or diadelphous; flowers papilionaceous; fruit a legume . . . (Papilionaceæ), Pea Family, p. 89

Numerous, distinct; flowers regular of 4 or 5 sepals and petals; fruit a legume . . . . . . (Mimoseæ), Acacia Family, p. 95

5 or fewer, petals minute and scale-like (or none); fruit a loosely covered 1-seeded indehiscent pod enclosed in the persistent calyx; stipules papery (Illecebraceæ), Sand Mat Family, p. 57

Stamens on a disk, not simulating a calyx tube

Inserted on the inner margin of the disk, as many or twice as many as the petals and alternate with them (usually 5); ovary 1-celled, 1-ovuled; fruit a berry
(Anacardiaceæ), Poison Oak Family, p. 101

Inserted on the outer margin of the disk, as many as the petals and opposite them (petals sometimes wanting); style or stigma 2–4-lobed; fruit a berry or dry pod with 2–4 hard seeds
(Rhamnaceæ), Buckthorn Family, p. 103

5–8, corolla irregular with 4 or 5 unequal petals; ovary 3-celled, ovules 6, only 1 maturing . . . . (Æsculus), Buckeye, p. 102

3–12 (usually 8); flowers perfect with petals, or diœcious and apetalous; fruit of 2 parts, each winged (*f*. Fig. 169, II; *e*. Fig. 172, II)
(Acer), Maple, p. 102

Ovary distinctly inferior.

Stamens perigynous (on the calyx)

Stamens 4–8, sepals and petals 4; ovary 4-celled
(Onagraceæ), Evening Primrose Family, p. 111

Stamens numerous, usually some petaloid, petals and sepals 5; herbage adhesive with barbed hairs
(Loasaceæ), Blazing Star Family, p. 115

Stamens, petals, and sepals numerous; fruit fleshy, 1-celled; spiny, leafless plants . . . (Cactaceæ), Cactus Family, p. 115

Stamens and petals numerous, sepals 5, capsules 3–5-celled; leaves and stems fleshy . . (Ficoideæ), Fig Marigold Family, p. 116

Stamens numerous; ovary 3–5-celled, opening at the top; calyx falling off like a lid, setting free the stamens and producing a tassel-like blossom . . . . (Eucalyptus), Gum Tree, p. 110

Stamens epigynous (on the ovary)

Stamens, petals, and sepals 5 (the last very small), styles 2; fruit a pair of seed-like carpels; flowers small in umbels; leaves alternate, compound . . . (Umbelliferæ), Parsley Family, p. 117

Similar to *Umbelliferæ*, except the styles and carpels 4 or 5; fruit a berry, and umbels panicled
(Araliaceæ), Ginseng Family, p. 116

Stamens, sepals, and petals 4; fruit a 1-seeded berry; flowers in cymes or heads; leaves simple, opposite
(Cornaceæ), Dogwood Family, p. 119

Division III. Gamopetalæ. Petals united into a cup or tube.

Ovary free from the calyx (superior).

Corolla regular.

Ovary deeply 4-lobed, in fruit forming 4 nutlets
(Borraginaceæ), Borage Family, p. 137

Ovary 2-celled, ovules numerous; fruit often a berry
(Solanaceæ), Nightshade Family, p. 145

Ovary 2-celled (generally 4-ovuled); twining plants
(Convolvulaceæ), Morning-glory Family, p. 132

Ovary 1-celled or imperfectly 2-celled, styles 2-cleft or entire
(Hydrophyllaceæ), Baby-eyes Family, p. 133

Ovary 3-celled with axillary placenta, style 3-lobed
(Polemoniaceæ), Phlox Family, p. 130

Ovary 1-celled with 2 parietal placentæ, style 1, stigmas 2
(Gentianaceæ), Gentian Family, p. 128

Ovary cells as many as petals, style 1, anthers 2-celled, opening by holes at the top . . (Ericaceæ), Heather Family, p. 120

Ovary 1-celled with axillary placenta, stamens opposite the petals
(Primulaceæ), Primrose Family, p. 125

Ovary 5-angled, 1-celled, 1-seeded, styles 5
(Plumbaginaceæ), Sea Pink Family, p. 127

Ovary 2-celled (sometimes 3-4-celled) with 1 seed in each cell (sometimes more in *Plantago major*)
(Plantaginaceæ), Plantain Family, p. 153

Ovaries 2, distinct, with a stigma common to both and united with a crown-like column of stamens; flowers in umbels; seeds with a tuft of silky hairs; plants with milky juice
(Asclepiadaceæ), Silkweed or Milkweed Family, p. 129

Similar to *Asclepiadaceæ*, except that the stamens are distinct and free from the stigma, but the anthers are disposed to cohere with it
(Apocynaceæ), Dogbane Family, p. 130

Corolla irregular. Fertile stamens fewer than the divisions of the corolla.

Ovary deeply 4-lobed, becoming 4 nutlets; corolla 2-lipped; aromatic herbs or shrubs . . . (Labiatæ), Mint Family, p. 139

Ovary 2-celled, seeds many on a central placenta, style and stigma 1
(Scrophulariaceæ), Figwort Family, p. 146

Ovary 2-celled with 2 or more parietal placentæ, seeds many; root-parasites without leaves or green color
(Orobanchaceæ), Broom Rape Family, p. 153

Ovary adnate to the calyx (inferior).

Ovary with as many cells as petals, anthers 2-celled, opening by holes at the top (*f.* Fig. 160, III; *e.* Fig. 138, III); fruit a berry
(Vaccinium), Huckleberry, p. 120

Ovary 2-5-celled (sometimes becoming 1-celled); fruit a berry; leaves opposite, without stipules
(Caprifoliaceæ), Honeysuckle Family, p. 156

Ovary 2-5-celled; leaves opposite with stipules, or whorled and without stipules . . (Rubiaceæ), Madder Family, p. 154

Ovary 1-3-celled; flowers monœcious or diœcious; trailing or climbing tendril-bearing herbs; fruit fleshy, indehiscent
(Cucurbitaceæ), Gourd Family, p. 158

Ovary 2-5-celled, with axillary placenta, style 2-5-cleft
(Campanulaceæ), Harebell Family, p. 159

Ovary 2-celled with axillary placenta, or 1-celled with parietal placentæ; stamens united by both filaments and anthers
(Lobeliaceæ), Lobelia Family, p. 160

Ovary 3-celled, 2 cells empty, fruit 1-seeded; stamens 3, corolla tubular, slightly irregular, border of the calyx plumose or wanting
(Valerianaceæ), Valerian Family, p. 158

Ovary 1-celled, becoming an akene, stamens united by their anthers (*f.* Fig. 153; *e.* Fig. 131); flowers many, combined in heads and appearing like a single flower (*f.* Fig. 133; *e.* Fig. 110)
(Compositæ), Sunflower Family, p. 161

CLASS I. — GYM'NOSPERMS

Plants destitute of a closed ovary, style, or stigma; ovules generally borne naked on a carpellary scale, which forms part of a cone. Cotyledons often several.

CONIF'ERÆ. Pine Family

Trees or shrubs with wood of peculiar structure, destitute of ducts, with resinous and aromatic juice. Leaves generally evergreen and needle-shaped or scale-shaped. Flowers destitute of floral envelopes, monœcious or diœcious. Male flowers consisting of stamens arranged in a spike, and resembling a catkin, with pollen sacs at the base of scales, subtended by a cluster of bracts like an involucre. Female flowers consisting of naked ovules at the base of scales arranged in a spike with a cluster of bracts below, in fruit forming a cone with the seeds under the scales or becoming a one- to few-seeded berry.

I. JUNIP'ERUS, Juniper, Cedar

Flowers diœcious, axillary or terminal. Staminate clusters numerous, with scales whorled or opposite, on a central axis, and 2–6 anther cells to each scale. Pistillate clusters of 3–6 fleshy scales, each bearing 1–2 erect ovules. *Fruit a berry. Seeds bony.* Shrubs or low trees, usually branching irregularly, with aromatic wood and thin, shreddy bark. *Leaves either triangular, scale-like, folding over each other, or linear, rigid, pointed, and free from each other.*

II. CUPRES'SUS, Cypress

Monœcious. Staminate clusters small, very numerous, and at the tips of tiny branchlets; pollen sacs 3–5 at the base of each scale. Fertile clusters erect on short lateral branchlets, *forming, when ripe, roundish or oblong woody cones, consisting of 6–10 very thick, shield-shaped scales, fitting closely together;* cones maturing in two years in all except the last; ovules numerous, in several rows at the base of the scales, forming acutely angled seeds. Leaves evergreen, scale-shaped, imbricated. When the tree is allowed to grow naturally, it is pyramidal, or roundish, with rather loose, straggling branches and pointed or rounded at the top. In bloom in winter or early spring.

a. **C. macrocar′pa Hartweg.** MONTEREY CYPRESS. This has dense foliage and *oblong cones* clustered on short stems. It is extensively cultivated throughout California for wind breaks and hedges; also trimmed into the most fantastic shapes, which are supposed to be ornamental.

b. **C. Govenia′na Gordon.** MOUNTAIN CYPRESS. This is a more loosely branched and smaller tree, with the upper branches slender and drooping. *The cones are an inch or less long, and are globose, rarely oblong.* This, too, is cultivated. In its native state it grows throughout the Coast Mountains.

c. **C. Macnabia′na Murr.** This is a small tree with *fine foliage very fragrant, sprinkled all over with white glands,* so that the tree is pale green. The *cones are small, with horn-like projections on the scales.* This also is cultivated, but rarely. It is a native of the mountains of Lake County.

d. **C. Lawsonia′na Murr (Chamæcy′paris).** PORT ORFORD CEDAR. This differs from the other species of *Cupressus* in having flattened, 2-ranked branches, and the *cones ripening in one year. Cones very small, $\frac{1}{3}$ of an inch in diameter, globose,* with 8 or 10 flat scales which are bluish green when young. Seeds 2–4 to each scale, somewhat winged. This is a tall, symmetrical tree with slender branches, often drooping. It is frequently cultivated and is a very valuable timber tree. The wood is very fragrant and is used in making chests and cupboards where it is desirable to keep out insects. It is also known as *Oregon Cedar* and *Ginger Pine.* It is found chiefly in the Coast Mountains of Oregon.

III. THU′YA, Arbor-vitæ

Monœcious. Staminate flowers numerous, very small, with 3 or 4 pollen sacs at the base of the 4–6 pointed scales. Fertile clusters at the ends of branchlets. *Cones very small, $\frac{1}{2}$ inch long, soon reflexed, ripening in one year, with 8–12 erect* *scales in pairs, having a pair of winged seeds under all except the top and bottom pair.* These are tall, symmetrical trees, with horizontally flattened branches and scale-shaped, evergreen leaves adnate and decurrent in 4 rows, with the tips free.

T. gigante′a Nutt. This is a very tall tree found in the Coast Mountains of Oregon, in Washington, northern Idaho, and British Columbia. The cones are densely clustered at the ends of the drooping branchlets, and the foliage is a bright, shining green. The bark is thin and fibrous, the wood soft but durable.

IV. LIBOCE′DRUS, Incense Cedar

Similar to *Thuya*, but with *12 or more scales on the staminate cluster and with the cones not reflexed.* These consist of *4–6 thick scales in pairs,* the two largest only bearing seeds. Seeds with unequal wings.

L. decur′rens Torrey. This becomes a large tree in the Sierra Nevada Mountains and has a trunk resembling that of the giant Sequoia. It is also found on almost all the higher hills of the Coast Mountains.

V. SEQUOI′A, Redwood

Monœcious. Staminate flowers small, very numerous near the ends of young shoots, with 3–5 pollen sacs under each scale. Fertile flowers at the ends of branchlets, consisting of *several scales with long-pointed tips which become bristles on the shield-shaped scales of the cone. Each scale is diamond-shaped with lines running to the center, giving the cone a quilted appearance.* The Sequoias are the largest trees on earth. Their leaves are flattened or triangular scale-shaped; the bark very thick, fibrous, and spongy; the wood red and soft, easily split longitudinally, and the bark also cleaving longitudinally. Both species are cultivated in different parts of California.

a. **S. semper′virens Endl.** REDWOOD. Cones small, oblong, of about 20 scales, maturing in one season; *lower leaves flat, 2-ranked; upper leaves, on tall trees, scale-shaped.* This forms immense forests in northern California and extends, along the coast, from southern Oregon to Point Gorda in Monterey County. The specific name arises from its tenacity of life. It sends up new trees in a circle around where a tree has been cut down. In bloom in winter.

b. **S. gigante'a Decaisne.** MAMMOTH SEQUOIA, BIG TREE. *Upper and lower leaves alike, scale-shaped, with long-pointed tips;* cones about 2 in. long of 25–30 scales, requiring two seasons to ripen. This is found in groves in moist, protected valleys in the higher Sierras, from Placer County through Tulare County.

VI. A'BIES, Fir

Tall trees tapering from a rather broad base to a pointed top, with horizontal branches and brittle wood that soon decays. Leaves apparently in 2 ranks, generally erect, twisted at base. *Cones erect, near the top of the tree, the scales and seeds falling away from the axes, which remain like candles on a Christmas tree.* The cones are therefore never found under the trees, only the fallen scales.

a. **A. con'color Lindl.** WHITE FIR. Large trees with old bark rough, gray, and furrowed. *Leaves pale green, obtuse.* Cones 3–5 in. long, green or purple when ripe. This is the common fir of middle elevations in the Sierra Nevada Mountains. It also extends into Oregon.

b. **A. gran'dis Lindl.** Tall and large trees with smooth, brownish bark. *Leaves dark green and glossy on the upper surface,* with 2 white lines on the lower, obtuse or notched at apex. Cones 2–4 in. long. This is probably the tallest fir in the world. It is found near the coast from northern California to British Columbia and is one of the most important sources of lumber.

VII. PI'CEA, Spruce

Tall trees, shaped as the firs, and with soft but strong wood. Leaves *sessile,* spirally arranged, falling from the branchlets as soon as dry and leaving the stems covered with numerous tiny projections, sometimes appearing in 2 ranks. *Cones drooping, growing on the upper branches, falling to the ground when ripe and always to be found under the bearing trees with the scales spirally arranged on the axes.*

a. **P. Sitchen'sis Carr.** TIDELAND SPRUCE. Very tall and large trees with thin, scaly, brownish red bark. Leaves slender, sessile, with short points at the apex. Cones 1½–3 in. long, yellowish.

This is one of the most important trees of the northern Pacific coast and is probably the largest spruce in the world. It extends from northern California to Alaska.

b. **P. Engelman′ni Engelm.** Engelmann Spruce, White Spruce. Bark light cinnamon-red, broken into thin loose scales. Young trees of pyramidal outline ; old trees in forests with long straight trunks and pyramidal at top. Leaves stiff, ending in a sharp tip. Branchlets pubescent. Cones cylindrical, about 2 in. long. Wood white, valuable as timber. This replaces the preceding species east of the Cascade Mountains.

VIII. TSU′GA, Hemlock Spruce

Similar to the true spruces but with *flatter leaves, having short petioles joined to a hard, woody, persistent base.* Seeds resinous on the surface and cones smaller. Tall trees of pyramidal outline and slender, drooping branchlets.

a. **T. heterophyl′la Sargent.** Bark thick, reddish brown. Cones less than an inch long, ovate. This is found along the coast from northern California to Alaska and is one of the most important timber trees.

b. **T. Mertensia′na Sargent (T. Pattonia′na).** Patton's Spruce, Hemlock Spruce. Trees with thick, cracked bark, reddish gray and apt to be scaly. Cones long and slender, 2–3 inches in length. Seeds with wings almost twice their length. This is shrubby at great elevations, but when favorably situated becomes a tree more than a hundred feet high. The apex is slender and pendent and the trunk generally slopes at base. It is found in the higher Sierra Nevada Mountains and northward to Alaska, where it grows along the coast.

IX. PSEUDOTSU′GA, Douglas Spruce

Flowers monœcious, from the axils of last year's leaves. Staminate clusters subtended by conspicuous involucres of bud scales ; pollen scales with 2 oblong pollen sacs tipped by an awl-shaped spur. Fertile clusters near the ends of branchlets, dark red or yellowish green, with scales concealed by 2-lobed, long, pointed bracts. Cones oblong, drooping, maturing in one year, but remaining on the trees after the seeds have fallen out. The leaves are flat and 2-ranked, on short petioles. This can easily be distinguished from other conifers by the *fringe-like bracts over the scales of the drooping cone.*

P. mucrona′ta Sudw. (**P. Douglas′ii Carr**), (incorrectly called OREGON PINE and RED FIR). This is found in California and Oregon, and usually grows near streams. It becomes a very tall tree. The wood is yellow or reddish and rather coarse, and the bark is fissured.

X. PI′NUS, Pine

Monœcious. Staminate clusters crowded at the base of the young shoots of the season; pollen scales spirally arranged, forming an elongated, cylindrical cluster, with 2 pollen sacs to each scale (Fig. 1, *2*). Fertile flowers of spirally arranged carpel scales on an axis, each scale bearing 2 ovules at base (Fig. 1, *3*). Fruit a cone ripening the second year, but often remaining unopened on the tree several years. Leaves evergreen, needle-shaped, in bundles of from 2–5, enclosed in a sheath of membranous scales (Fig. 1, *d*). Seeds generally winged (Fig. 1, *4*).

a. **P. Lambertia′na Dougl.** SUGAR PINE. *Leaves 5 in a sheath, 3–4 in. long.* Cones long, narrow, cylindrical, from a *foot* to more than *2 ft.* long when fully grown, pendent at the ends of the branches the second year, *the scales without knobs or prickles.* This is a very tall and large pine, with the upper branches widely spreading and with irregular and picturesque outlines. It is common in the Sierra Nevada Mountains at moderately high elevations and on most of the high peaks of the Coast Mountains, extending into Washington and Oregon.

b. **P. montic′ola Dougl.** SMALL SUGAR PINE. This is a smaller tree than the preceding but similar, with *leaves 5 in a sheath, about 2 in. long. Cones 3–8 in. long*, with the scales without knobs or prickles, reflexed when the seeds are ripe. This is common in the higher Sierra Nevada Mountains, especially northward, and extends into Oregon and Washington at lower elevations.

c. **P. pondero′sa Dougl.** YELLOW PINE. *Leaves 3 in a sheath,* 5–11 in. long, rather thick. *Cones oval, 3–5 in. long, sessile*, spreading or recurved, generally several together; scales with stout prickles. Wings on the seeds not quite an inch long, widest above the middle. This is one of the largest pines of the coast. It is found in the mountains in the same region as the Sugar Pine but more widely distributed. The variety **Jeffreyi** is found generally at higher elevations and has longer, coarser leaves, and much larger cones. This is the most widely distributed species and one of the most prized timber trees.

d. **P. contor'ta Dougl.** *Leaves 2 in a sheath,* short. Cones small and slender, 1–3 in. long, whorled, oblique, often remaining closed for many years; *scales with strong knobs and delicate prickles.* This is a small tree. It is found along the coast from California to Alaska.

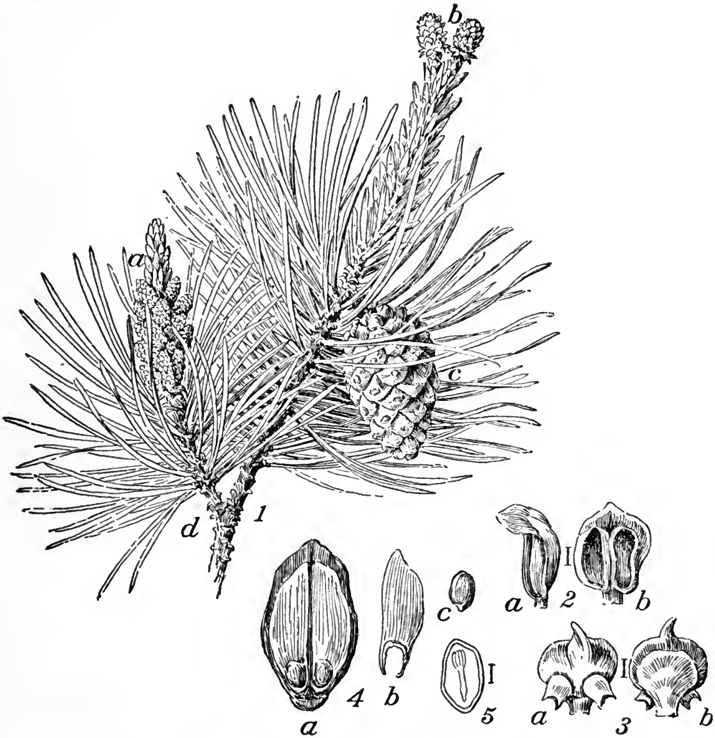

FIG. 1.—Scotch Pine (*P. sylvestris*).

1, a twig showing: *a*, staminate catkins; *b*, pistillate catkins; *c*, a cone; *d*, needles. *2*, an anther: *a*, side view; *b*, outer surface. *3*, a carpel scale: *a*, inner surface; *b*, outer surface. *4*, a cone scale, a seed wing, and a seed. *5*, section of a seed, showing the embryo. *1* is natural size; the other parts of the figure are magnified by the amount indicated by comparison with the vertical line alongside each.

The variety **Murrayana** is a tall, straight tree, growing in the mountains and known as Lodge-pole Pine, from the use made of the slender, straight stems by the Indians. It is widely distributed and variable.

e. **P. radia′ta Don (P. insig′nis Dougl.).** MONTEREY PINE. *Leaves 3 in a sheath,* 4–6 in. long, slender, lax, closely serrate, bright green, densely clustered. *Cones encircling the stem, deflexed on short stems, pointed, curved inwards, owing to the difference between the inner and outer scales.* The cones remain on the tree two or more years without opening. This pine is most extensively cultivated in California for wind-breaks. It grows nearly 100 ft. in height.

f. **P. attenua′ta Lemmon (P. tubercula′ta Gord.).** KNOB-CONE PINE. *Leaves 3 in a sheath,* 4–7 in. long. *Cones in whorls, often with several whorls in a bunch, strongly reflexed on short stems, oblique,* tapering to a very narrow base, with the apex pointed; *the outer scales are enlarged and conical, the inner flatter, both tipped with stout prickles.* The cones persist on the stems and branches many years without opening. This is a small tree and often begins to bear cones when a foot or two high. It is found in the Coast Mountains and in the foothills of the Sierra Nevada Mountains.

g. **P. Sabinia′na Dougl.** NUT PINE, BULL PINE, DIGGER PINE. *Leaves 3 in a sheath, 8–12 in. long, light glaucous green, slender, drooping;* cones massive, short-oval, 6–10 in. long, 5–7 in. in diameter near the base, *deflexed on short, stout stems; scales with stout, claw-like projections.* The nuts are edible and have a stony shell, and formed an important part of the food of the Digger Indians. This tree generally has loose spreading branches and is very graceful. The long light-green foliage easily distinguishes it from other pines. The cones often remain on the branches several years after the seeds have fallen out. This pine is the most common in the foothills of the Sierra Nevada Mountains and in the valleys of the Coast Mountains.

CLASS II. — AN′GIOSPERMS

Plants with a closed ovary, in which the seeds are matured. Cotyledons 1–2.

SUBCLASS I. — MONOCOTYLED′ONOUS PLANTS

Stems with the fibro-vascular bundles scattered amid the parenchyma cells (*f.* Fig. 52; *e.* Fig. 54); in perennial plants no annual rings of wood. Leaves usually parallel-veined, alternate, nearly entire. Parts of the flower generally in threes (never in fives). Cotyledon 1.

GRAMIN′EÆ. Grass Family

Mostly herbs, with usually hollow stems, closed and enlarged at the nodes. Alternate leaves, in 2 ranks, with sheathing bases, which are split open on the side opposite the blade. The flowers are nearly or quite destitute of floral envelopes, solitary, and borne in the axils of scaly bracts called glumes, which are arranged in 2 ranks overlapping each other on

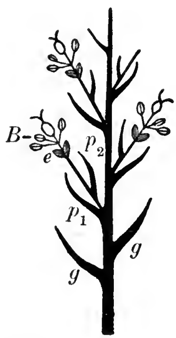

FIG. 2. — Diagram of Inflorescence of a Grass.

g, sterile glumes; p_1, a flowering glume; p_2, a scaly bract (palea); *e*, transparent scales (lodicules) at the base of the flower; *B*, the flower.

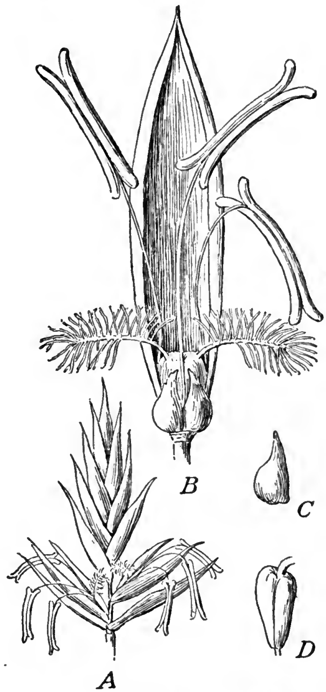

FIG. 3. — Fescue-grass (*Festuca pratensis*).

A, spikelet (compare Fig. 2); *B*, a flower, the lodicules in front and the palea behind; *C*, a lodicule; *D*, ovary.

1–many-flowered spikelets; these are variously grouped in spikes, panicles (*f.* Figs. 136, *A*, *B*, *C*; *e.* Fig. 183), and so on. The fruit is a grain.

(The family is too difficult for the beginner, but the structure and grouping of the flowers may be gathered from a careful study of Figs. 2, 3.)

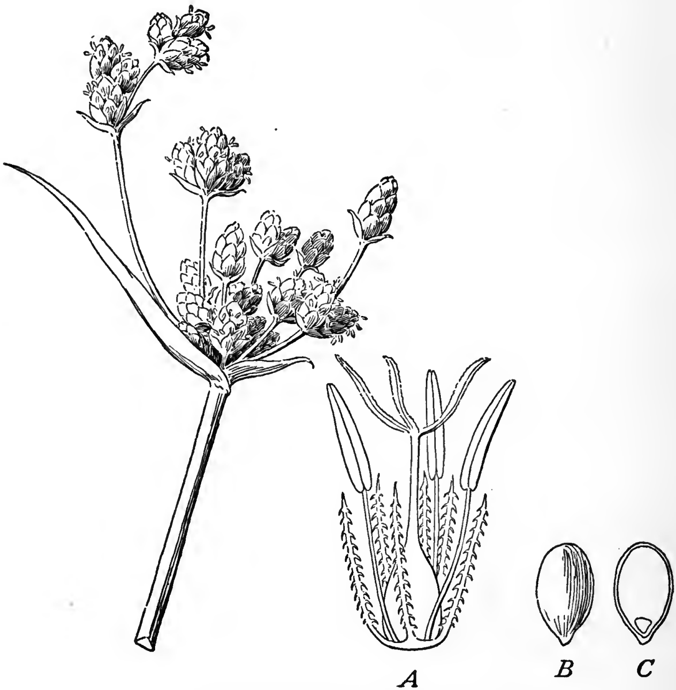

FIG. 4.—Inflorescence, Flower, and Seed of a Sedge. (Great Bulrush, *Scirpus lacustris*.)

A, magnified flower, surrounded by a perianth of hypogynous bristles; *B*, the seed; *C*, section of the seed, showing the small embryo enclosed in the base of the endosperm.

CYPERA'CEÆ. SEDGE FAMILY

Grass-like or rush-like herbs, with solid, usually triangular stems, growing in tufts. The sheathing base of the generally 3-ranked leaves, when present, is not slit as in grasses. The flowers are usually somewhat less enclosed by bracts than those of grasses; the perianth is absent or rudimentary; stamens generally 3; style 2-cleft or 3-cleft.

The flower cluster and the flower may be understood from an inspection of Fig. 4.

The species are even more difficult to determine than those of grasses.

ARA′CEÆ. Arum Family

Smooth, perennial herbs, generally growing in wet places. Leaves large, radical or alternate. Flowers sessile, crowded on a spadix which is surrounded by a broad sheathing spathe. Perianth in our representative with 4 divisions. Ovary 2-celled and 2-ovuled. Fruit consisting of berries which coalesce on the spadix.

LYSICHI′TON, Skunk Cabbage

Leaves large, 1–3 ft. long and often a foot broad, growing from a thick rootstock. Spadix at first covered by a yellowish green spathe, later extending beyond it on a stout peduncle. Flowers covering the spadix. Stamens 4, opposite the segments of the perianth, with 2-celled anthers opening upwards.

L. Kamtschatcen′sis Schott. This is found in swamps from northern California to Alaska. It blooms in May and June. It is a beautiful plant with large, broad leaves, covering the swamps, but it has a strong and disagreeable odor, from which the common name is derived.

LILIA′CEÆ. Lily Family

Herbs. Flowers regular and symmetrical, with their parts 3 or some multiple of 3. Ovary 3-celled, free from the perianth. Fruit a capsule or berry. Seeds with endosperm (*f.* Fig. 5; *e.* Fig. 8, 1).

I. AL′LIUM, Wild Onion

Plants with the odor and taste of onion. Scape from a coated bulb. Involucre with papery bracts. *Pedicels not jointed under the flowers.* Perianth rose-color or white. Stamens 6, with filaments broadening towards the base, attached to the perianth. *Ovules 2 in each cell of the ovary,* rarely all ripening. (There are many species, difficult to determine. The most common are given.)

a. **A. serra′tum Watson.** Scape nearly a foot high. Perianth dark rose-color, with divisions in 2 sets, dissimilar. Ovary with wart-like crests at summit. *Outer bulb coats marked with a horizontally zigzag veining which tears readily along the veins.* This is common and abundant wherever found.

b. **A. unifo′lium Kellogg.** Scape usually 2 ft. or more high. Flowers pale rose-color or white, from 10 to 30 in the umbels. *Ovary smooth at summit. Bulb propagating by a side offshoot,* the white outer coats marked by a delicate, complicated veining. This grows in wet places and generally has more than one leaf.

c. **A. acumina′tum Hook.** Crimson-flowered Onion. Scapes 4–6 in. high, from a bulb with outer coats, not fibrous, but marked with hexagonal or quadrangular venation. Leaves narrowly linear. Bracts of the involucre 2. *Flowers crimson, on pedicels nearly an inch long, in erect umbels. Segments of the perianth recurved, with long, pointed tips, the inner ones wavy and minutely serrate.* Generally growing in adobe soil, blooming in spring and early summer. It is found chiefly on the eastern side of the Sierra Nevada Mountains and north to British Columbia.

d. **A. attenuifo′lium Kellogg.** Scape slender, from 6 in. to more than a foot high. Leaves narrow, becoming thread-like at tip. Bracts of the umbel 2, short, acute. Umbel with many white flowers. Segments of the perianth pointed, longer than the stamens. *Ovary with 6 crests at summit. Bulb coats often reddish, with a fine, wavy veining.* This is found in wet places in the Coast Mountains, in the Sierra Nevada Mountains, and it extends into Oregon.

e. **A. falcifo′lium H. and A.** *Scape low, flat, 2-edged. Leaves 2, flat, broad, sickle-shaped.* Bracts 2. Flowers deep crimson, the segments of the perianth edged with minute, glandular teeth. *Capsule pointed with short, narrow crests.* Bulb large and globular, the markings on the coats not distinctive. This is found in sandy or gravelly places on the hills of the Coast Mountains, especially northward, extending to Oregon.

II. MUIL′LA

Similar to *Allium, but without the odor and taste.* Flowers greenish yellow. Bracts of the umbels from 4 to 6, linear-lanceolate. *Ovules 8–10 in each cell of the ovary.*

M. marit′ima Watson. This is found in the interior of the state and along the coast, frequently growing in alkaline soil. The flowers have a delicate perfume.

III. BLOOME′RIA, Golden Stars

Perianth of 6 nearly equal, spreading divisions; light orange, with a dark midnerve of 2 closely parallel lines. Pedicels jointed under the perianth. *Stamens 6, with slender filaments nearly as long as the perianth, — each, at base, attached to a short 2-toothed, hairy appendage; these uniting to form a cup at the base of the perianth.* Ovules several in each cell of the ovary.

B. au′rea Kellogg. Golden Bloomeria, Golden Stars. Bulb small, densely covered with brownish fibers. Flowers usually numerous in the umbel. Capsule beaked with the persistent style. From Monterey to San Diego, and abundant wherever found.

IV. BRODIÆ′A, generally known as BRODIÆA, sometimes called Wild Hyacinth

Corm coated with brownish fibers (sometimes tissue-like), flat on the bottom when the old part is removed. Leaves generally withering soon. *Pedicels of various lengths, jointed under the perianth.* Flowers withering and persisting, white, blue-purple, rose-color, yellow, or scarlet; in shape tubular, rotate, or funnel-form. Stamens in 2 sets, 3 or 6, attached to the tube of the perianth, often with wing-like appendages on the filaments; when 3, alternating with petal-like staminodia. (Staminodia are filaments, usually broadened, without anthers.)

(There are 5 subgenera which Professor Greene regards as genera; so, to avoid confusion, the species are arranged under the subgenera.)

SUBGENUS **DICHELOSTEM′MA.** *Perianth tubular, 3 stamens with erect anthers and wing-like appendages on each side of the filaments, the other 3 free or reduced to staminodia.*

a. **B. capita′ta Benth.** GRASS NUTS, BRODIÆA, WILD HYACINTH (often incorrectly WILD ONIONS). Flowers blue-purple (rarely white), in a close umbel, like a head. Bracts of the involucre membranous, dark purple. *Stamens with anthers 6, the inner anthers nearly sessile with wing-like appendages, the outer free, on short filaments; the appendages of the inner anthers form a crown in the throat of the perianth.* This is abundant and widely distributed. The children eat the bulbs and call them "grass nuts."

b. **B. volu′bilis Baker (Strophilir′ion).** TWINING HYACINTH. Perianth rose-color, with a 6-angled tube nearly as long as the divisions. *Three stamens with anthers and wing-like appendages, 3 emarginate staminodia. Scape long, twining snake-like around other stems.* The color of the flowers and shape of the umbel might lead one to suppose this a wild onion. It is common in the foothills of the Sierras and is found also in the Coast Mountains.

c. **B. coccin′ea Gray (Brevoor′tia).** FIRECRACKER FLOWER. Perianth with a scarlet tube nearly an inch long, and 6 short and broad green divisions. *Three stamens with wing-like appendages, 3 staminodia.* The staminodia and appendages are yellow. The scape is long and wavy, but not twining. These brilliant flowers hang, as if too heavy to stand erect on their slender pedicels. Northern California.

SUBGENUS **HOOK′ERA.** *Perianth tubular-funnel-shaped with a spreading border. Flowers purplish blue, lighter colored at base, thick in texture. Pedicels unequal. Stamens 3, with erect anthers alternating with 3 petal-like staminodia.*

d. **B. grandiflo′ra Smith.** Scape from a few inches to a foot in height. Pedicels 3–10, curved outwards and upwards, from 1 to 4 in. long. Anthers twice as long as the slender filaments. *Staminodia white, tongue-shaped, as long as the anthers.* The flowers of this are sometimes nearly an inch long. This blooms in summer later than other species growing in the same localities. Quite common.

e. **B. terres′tris Kellogg.** GROUND LILY. Scape scarcely appearing above the surface of the ground. Flowers smaller than the last. *Staminodia yellowish, emarginate, folded backwards.* Common in central California and extending northwards.

SUBGENUS **CALLIPRO′RA.** *Stamens 6, with versatile anthers. Filaments attached to the throat of the perianth, winged their entire length, 3-forked at top, with the anther on the middle prong.*

f. **B. ixioi'des Watson.** Golden Brodiæa. Perianth funnel-form, with short tube and spreading divisions which are yellow with a brown midvein. Capsule on a stipe.

SUBGENUS **TRITELE'IA.** *Stamens 6, 3 on the throat, 3 below on the tube, with no appendages on the filaments. Anthers versatile. Capsule on a stipe.*

g. **B. lax'a Watson.** Grass Lilies, Ithuriel's Spear, Blue Milla. Scape erect from 1 to 2 ft. high. Flowers usually many, on pedicels 2–4 in. long, blue to violet (sometimes white). *Perianth funnel-form, narrow at base.* Capsule on a prominent stipe. This is common and very lovely. The flowers are sometimes an inch or more long. From Kern County to northern Oregon.

h. **B. Douglas'ii.** Scape stout, erect, a foot or two high. Leaves keeled. Flowers blue, on short pedicels. *Perianth broadly tubular,* with lobes about as long as the tube. Oregon and Washington.

SUBGENUS **HESPEROCOR'DUM.** *Stamens 6, filaments without appendages, equal, dilated, and united at base.*

i. **B. lac'tea Watson.** Scape slender, from 1 to 2 ft. high. Flowers numerous, on pedicels from 1 to 2 in. long. Perianth funnel-form, thin in texture, white with a green midvein on each division. Anthers yellow or purple, erect. Capsule almost round, beaked by the pointed style, stipitate. In northern California and north to Washington.

V. LIL'IUM, True Lilies

Flowers in racemes or whorls on tall, leafy stems. *Bulbs formed of thick, lanceolate scales.* Perianth deciduous, funnel-form, with 6 nearly equal, spreading divisions. Anthers linear, versatile, on long filaments. Ovary sessile. Fruit a pod, with 2 rows of flat seeds in each cell. Leaves often in whorls, *net-veined.* Bracts leaf-like. Nectary a narrow groove.

a. **L. Washingtonia'num Kellogg.** Washington Lily. Stems simple, from 2 to 5 ft. high. Leaves in whorls of from 6 to 10, oblanceolate. *Flowers large, pure white, or dotted with purple, fading purplish, from 2 to 20, hanging on ascending pedicels in a simple or compound raceme.* Perianth divisions not recurved. The flowers are fragrant, from 3 to 4 in. long and spreading nearly as wide. This fine lily generally grows in the shade, in the higher Sierra Nevada Mountains and in Oregon.

b. **L. pardali′num Kellogg.** TIGER LILY, LEOPARD LILY. Stems simple, 3–7 ft. high, from a bulb like a thick rootstock, forming clumps. *Leaves acuminate in whorls of from 9 to 15*, lanceolate, pointed, 3-nerved, varying in width. Flowers in racemes, the lowest often whorled, nodding at the ends of long spreading pedicels. *Perianth orange below, spotted with reddish purple;* segments curled backwards. Anthers red. This is frequent along streams under the trees, in the Coast and Sierra Nevada Mountains.

c. **L. Humbold′tii Roezl. and Leicht.** HUMBOLDT'S LILY, TIGER LILY. Stems stout, purplish, 4–8 ft. high, from bulbs 2–6 in. in diameter composed of fleshy, ovate-lanceolate scales 2–3 in. long. *Leaves large, with undulate, rough margins*, in 4–6 whorls and with 10–20 in each whorl. *Flowers large, drooping, on stout widely spreading pedicels which are from a few inches to nearly a foot long. Segments of the perianth 3–4 in. long, reddish orange, spotted with purple*, curled back. Stamens about equaling the style, anthers red. Capsule large, sharply 6-angled. This blooms in summer and is frequent in the foothills of the Sierra Nevada Mountains and south to near San Diego.

d. **L. par′vum Kellogg.** SMALL TIGER LILY. Stems slender, 1 to more than 6 ft. high, from a small bulb composed of short, thick, jointed scales. Leaves scattered or in whorls, 2–5 in. long. *Flowers small, erect, or nearly so, on slender, almost erect pedicels. Segments of the perianth about an inch long, orange, spotted with purple*, reddish at the recurved spreading tips. Stamens almost as long as the style. Capsule roundish, less than an inch long. This is frequent in the Sierra Nevada Mountains and north to Oregon.

e. **L. Columbia′num Hanson.** Bulb small, with fleshy white scales closely folded over each other. Stems slender, 2–3 ft. high. Upper and lower leaves scattered, the others in whorls of 5–several, oblanceolate. Flowers nodding, few or many, on scattered, slender, curving pedicels. Perianth *bright orange spotted with purple, the segments 1–2 in. long*, revolute. Anthers yellow. Capsule an inch long, 6-angled. This beautiful lily is common in Washington and Oregon and is found in northern California.

VI. FRITILLA′RIA, Mission Bells, Rice Roots

Stems simple, leafy. *Bulb with round, thick scales, often like grains of rice.* Flowers in racemes, nodding on rather short pedicels. Perianth bell-shaped with separate divisions, nectary a shallow pit.

a. **F. lanceola′ta Pursh.** CHECKERED LILY. Leaves in from 1 to 3 whorls, lanceolate, 2–5 in. long. Flowers on slender pedicels, checkered variously in dark purple and greenish yellow. Pods with winged angles. *Bulb solid, not dividing into scales, but with rice-like grains over the whole upper surface.* In the Coast Mountains extending to British Columbia.

b. **F. biflo′ra Lindl.** CHOCOLATE LILY. Leaves scattered or sometimes whorled. Flowers 1–3, brownish red or sometimes greenish purple. Pod angled but not winged. *Bulb composed of thick, separable scales and without rice-like grains.* More common southward.

c. **F. recur′va Benth.** Stem rather stout and tall, generally more than a foot high. Leaves linear-lanceolate, in 2 whorls near the middle of the stem. *Flowers 1–9, scarlet spotted with yellow, obtuse at base.* This is found in the Sierra Nevada Mountains and it extends northward into Oregon.

d. **F. coccin′ea Greene.** This is similar to the above, but *the flowers are acute at the base.* It is found in the Coast Mountains.

e. **F. atropurpu′rea Nutt.** Stem 6 in. to a foot high. *Leaves scattered or whorled.* Flowers dull purplish or greenish, often imperfect, less than an inch across when expanded. *Pod with 3 short angles, broadest at the top.* From northeastern California to the Columbia River.

f. **F. pu′dica Spreng.** Stems 3–8 in. high. Leaves few, scattered or whorled. *Flowers generally solitary, yellow or orange and tinged with crimson.* Pod oblong, with angles obtuse. From east of the Sierra Nevada Mountains to British Columbia.

VII. ERYTHRO′NIUM, Dog-tooth Violet, Adder's Tongue

Scapes from an oblong, deep-seated corm, generally with a tooth-like offshoot. *Leaves broad, often mottled with brownish red, generallg 2 at the base, spreading in opposite directions. Flowers one or several in an umbel. Perianth nodding, open bell-shaped,* of 6 recurved divisions. Stamens 6, with erect anthers and slender filaments. Pods 3-sided.

a. **E. gigante′um Lindl.** Scape from 10 to 15 in. high. Flowers 1–6 in an umbel. Leaves often mottled, 6–10 in. long. Flowers cream-color, often tinged with pink or brown, yellow in the center. *Segments 1–2 in. long, much recurved.* In the Coast Mountains from Sonoma County to Washington.

b. **E. Hartwe′gi Watson.** Scape shorter. *Leaves generally mottled, sometimes 3.* Flowers pale yellow, orange at the center, with segments 1–1½ in. long, recurved but little. *Flowers on slender stems, from 1 to 5, in a sessile umbel.* This is found in the Sierra Nevada Mountains.

c. **E. grandiflo′rum Pursh.** *Leaves not mottled.* Flowers 1–6, yellow or cream color, with the base of the perianth white. Anthers purple.

Pods oblong, narrowed at base. This is common in Washington and Oregon.

VIII. YUC′CA, Spanish Bayonet, Soapweed

Leaves stiff and pointed like daggers, growing in a bunch. Flowers in a raceme or panicle. Perianth of 6 thick divisions, bell-shaped, nodding. Stamens with thick filaments attached to the base of the perianth. Ovary sessile. Stigmas 3, united. Fruit with cells incompletely divided. Seeds black, flat, 2 rows in each cell.

a. **Y. Whip′plei Torr.** Scape 4–12 ft. high and about 2 in. in diameter, clothed with sharp-pointed bracts close to the stem, rising from amidst a thick bunch of narrow, dagger-like leaves. Flowers in a panicle. Segments of the perianth cream-color, 1–2 in. long. The plant from which the scape springs dies after fruiting; but the dead scapes often remain standing like slender white posts on the hillsides.

b. **Y. arbores′cens Torr.** This is the tree Yucca of the Mojave Desert. *f.* Part I, Plate VII.

IX. CALOCHOR′TUS, Butterfly Tulip, Mariposa Lily

Perianth with 3 outer segments sepal-like, the 3 inner petal-like, each with a large honey-gland near the base, densely covered with hairs. Flowers erect or drooping, solitary, in racemes or in umbels, beautifully and variously colored. Stamens 6, with erect anthers. Seeds in 2 rows in each cell of the ovary.

a. **C. alb′us Dougl.** SATIN BELL, HAIRY BELL, ALABASTER TULIP. Flowers white, or pinkish with a satiny texture. *Segments of the perianth curved inwards, forming a close roundish bell in shape something like a sleigh bell, very hairy within.* Gland crescent-shaped, almost concealed by the long hairs of the perianth. Anthers linear-oblong, tipped by a blunt point. Capsule winged. The stems are rather tall, leafy and branching, bearing numerous flowers. This grows on shady banks in the Coast Mountains.

b. **C. pulchellus Dougl.** GOLDEN BELLS. Flowers shaped as the preceding, *yellow, hairy within and on the margins;* flowers rather few. This has been mistaken for the next, which is much commoner.

c. **C. amab′ilis Purdy.** DIOGENES' LANTERN. Similar to the above, but the flowers are more numerous, smaller, and *the segments of the perianth curve inwards so much that they overlap, hairy on the margin only.* This is common in northern California.

d. **C. amœ′nus Greene.** Rosy Bells. This is similar to *C. amabilis* in form, but is *deep rose-color.* It grows in the foothills of the southern Sierra Nevada Mountains.

e. **C. Ben′thami Baker.** Yellow Star Tulips. Flowers bell-shaped with incurved petals, *erect when open. Petals yellow,* densely covered with yellow hairs, the gland shallow and crescent-shaped above the brown claw. Capsules nodding on slender recurved pedicels. Low slender plants with from 2 to 6 flowers. Common in the Sierra Nevada Mountains from Mariposa to Siskiyou County.

f. **C. Mawea′nus Leicht.** Mouse-ears. Flowers less than an inch in diameter, with spreading divisions, *erect in full bloom, white or bluish.* Inner divisions of the perianth densely covered with long white or purplish hairs. Honey-gland semicircular. Anthers pointed. Capsule winged, nodding. Stems low, branched, with from 3 to 6 flowers. Common in northern California. Spring.

g. **C. el′egans Pursh.** Scape 2–3-flowered, generally shorter than the single grass-like leaf. Flowers on short thread-like pedicels which are not much longer than the bracts. Petals about ½ inch long, *white, with a smooth purple spot at base, covered on the inside with purple down. Pods nodding.* The roots are eaten by the Indians. It is found from Oregon and Idaho to British Columbia. Spring.

h. **C. uniflo′rus H. & A.** Scapes erect with 1–3 flowers. *Petals lilac,* an inch long, with the upper margin denticulate; *gland purple, densely hairy,* with a few scattered hairs on the petal above. *Pods nodding.* This is found in middle California near the coast. Spring.

i. **C. umbella′tus Wood.** Scapes low and often decumbent. Flowers generally many in 1–3 umbels or corymbs on long slender pedicels. Petals white or tinged with pink about ½ inch long, with some hairs on the lower half; gland covered with a narrow scale. *Pods obtuse at each end, nodding.* This is found on slopes of hills in the Coast Mountains of middle California. Spring.

j. **C. nu′dus Watson.** Low and slender with one leaf. Flowers 1–6 in one umbel. Petals white or pale lilac, fan-shaped, denticulate on the upper margin, *wholly without hairs;* gland shallow, divided by a transverse, denticulate scale. *Pod acute at each end, nodding.* This is found in the Sierra Nevada Mountains from the Yosemite northward. Early summer.

k. **C. clava′tus Watson.** Erect stems a foot or two high. *Flowers tulip-shaped,* erect. Sepals yellow on the inner side, with a brownish spot at base, greenish on the outer side. Petals yellow, with a deep, round gland surrounded by *yellow, club-shaped hairs.* Anthers purple, obtuse. Pod erect, narrowly oblong, with thick, obtusely angled cells. Southern California. Early summer.

l. **C. Weed′ii Wood.** Stem branching, leafy, a foot or more high. Sepals as long as the petals, orange on the inner side with a brown spot at base. Petals 1–1½ in. long, *fan-shaped, deep yellow, dotted and often margined with brownish purple, covered with slender yellow or purple hairs;* gland small, round, densely hairy. Pod erect, narrowed to the top, 1½ in. long. The variety **purpuras′cens Watson** has the *petals wholly purple or blotched with purple.* These are common in southern California. Early summer.

m. **C. lu′teus Dougl.** GOLDEN TULIP. Flowers *erect, tulip-shaped, greenish yellow,* and variously marked with brownish purple, slightly hairy within. Honey-gland round or crescent-shaped, densely covered with yellow hairs. Anthers yellow, linear-oblong, obtuse. Capsule erect, narrowed towards the top. This is the most widely distributed species and is quite variable. Early summer.

n. **C. lu′teus var. ocula′tus Watson.** This is similar to **C. luteus,** except in the color and markings of the petals. They are white, cream, or purple, with *a central brownish spot which is usually bordered with yellow.* The claw is yellow or purplish, and the gland is narrowly crescent-shaped and covered with brownish or yellowish hairs. This includes a great variety of color forms, and has a wide range. It is the commonest species in the northern Californian valleys, and is found in both the Sierra Nevada and Coast Mountains from Fresno County to Oregon. Early summer.

o. **C. Nuttal′lii Torr. & Gray.** Stem always bearing a small bulb at base. Flowers erect, tulip-shaped, 1–several in umbel-like clusters. Sepals ovate lanceolate with papery margins, generally yellowish within. *Petals white or tinged with lilac,* with a purplish spot above the yellow base. Gland round or oblong, densely hairy, and surrounded by long, scattered hairs. *Anthers obtuse, sagittate at base.* Capsule erect, narrowed upwards. This is found in the Sierra Nevada Mountains, especially northward, to Oregon. Early summer.

p. **C. venus′tus Benth.** BUTTERFLY TULIP. Flowers erect, tulip-shaped, white, often tinged with lilac, or purplish throughout, *generally marked with a red spot near the top of the petals, like a drop of blood.* Honey-gland *narrowly oblong,* hairy. The markings above the glands are beautiful and exceedingly variable. Pods erect. This is widely distributed in various forms. Early summer.

q. **C. splen′dens Dougl.** LILAC TULIP. *Flowers erect, tulip-shaped, lilac above with scattered white hairs, paler beneath.* Gland round, densely hairy, sometimes wanting. Anthers purple, obtuse or acute. Pods erect. This is common in the southern parts of California. Early summer.

r. **C. macrocar′pus Dougl.** Stems stout, erect, 1–2 ft. high, with 1–2 tulip-shaped flowers. Leaves 3–5, narrow, convolute. Sepals about as long as the petals, narrowly pointed, lilac on the inner side. *Petals obovate with pointed apex, 1½–2 inches long, dark lilac, paler at* *base and with a greenish line down the middle;* gland oblong, densely hairy, and with some scattered glandular hairs above. Pods erect, narrowed upwards, about 2 inches long. This is found from northern California to Washington and Idaho. Summer.

X. CAMAS′SIA, Camass

Flowers usually deep blue in a simple raceme with papery bracts. Perianth of 6 oblanceolate segments, spreading open. Stamens 6, on the base of the perianth. Style slender, with 3 divisions. This has a coated bulb and grows in swampy places. The flowers are rarely white.

C. esculen′ta Lindl. Scape from 1 to 2 ft. high. Leaves many, near the base, keeled. Style as long as the perianth. Stamens shorter, with awl-shaped filaments and linear, versatile anthers. The bulbs are eaten by the Indians. This grows through middle California and north to Washington. Early summer.

XI. CHLOROG′ALUM, Soap Plant, Amole

Stems almost leafless from a bulb, either fibrous or membranous-coated. *Leaves mostly radical, linear, with very wavy margins.* Flowering branches widely spreading, with the flowers scattered on short pedicels. *Perianth of 6 oblong spreading segments which persist and become twisted over the ovary.* Stamens 6, shorter than the segments, to which they are adnate at base. Capsule 3-lobed, broadest at top, with 1 or 2 black seeds in each cell.

C. pomeridia′num Kunth. Soap Plant, Amole. Bulb large, covered with coarse brown fibers. Leaves 6–18 in. long, and nearly an inch wide. Flowers with the white segments veined with purple, spreading widely from the very base. Pedicels nearly as long as the flowers. The flowers open suddenly in the afternoon, and are conspicuous on the leafless stems. The bulb is used as a substitute for soap. It is widely distributed and blooms in summer.

XII. ZYGADE′NUS

Stems stout from a deep bulb. Leaves linear, chiefly near the base of the stem. *Flowers in racemes or panicled racemes. Perianth greenish white, spreading star-like, with a greenish* *yellow gland at the base of the segments.* Stamens nearly free, with filaments at first recurved.

a. **Z. Fremon′ti Torr.** Bulb with outer coats almost black. Stems from a few inches to about 4 ft. high. *Racemes simple or compound,* with few or many flowers. Bracts leaf-like. *Flowers from less than a half inch to nearly an inch in diameter.* Perianth entirely free from the ovary; outer segments without a claw, inner with claws. Glands wavy. Stamens shorter than the perianth. Styles short. Capsule oblong, 3-lobed, septicidally dehiscent. Spring.

b. **Z. veneno′sus Watson.** DEATH CAMASS, HOG'S POTATO. Flowers smaller than the preceding, *generally in a simple raceme,* the lower sometimes staminate. Segments of the perianth from triangular-ovate to elliptical, with blades rounded or slightly cordate at base, all with claws. Capsule oblong-ovate with 2 seeds in each cell. This grows in wet meadows or along streams. The bulb is said to be poisonous, except to hogs. Spring.

XIII. SMILACI′NA, False Solomon's Seal

Stems from a horizontal rootstock, simple, leafy. *Flowers white, very small, in a simple or compound terminal raceme.* Anthers versatile on awl-shaped filaments. Fruit a berry.

a. **S. amplexicau′lis Nutt.** Stems from 1 to 3 ft. high. Leaves broad, half clasping the stem. *Flowers very small, in an oblong or pyramidal panicle.* Filaments equaling or even surpassing the divisions of the perianth in length and breadth. Fruit a light-red berry with darker dots. This is common in rich, shady woods. Spring.

b. **S. sessilifo′lia Nutt.** Stems not so tall. Leaves narrower and lighter green. *Raceme simple, with star-like flowers on spreading pedicels.* Stems half as long as the divisions of the perianth. Berry green with red lines, becoming dark red when fully ripe. This is common in shady woods. Spring.

XIV. DIS′PORUM (PROSAR′TES), Fairy Bells, Drops of Gold

Stems from a spreading rootstock, widely branching, leafy. Leaves alternate, sessile or clasping. *Flowers greenish white, bell-shaped, hanging under the leaves from the upper axils.* Fruit an orange or salmon-color berry.

a. **D. Menzie′sii Benth. & Hook.** *Perianth broad at base,* with divisions somewhat swollen. Stamens shorter than the perianth.

Style 3-cleft. Leaves ovate, pointed, often cordate at base. *Fruit a pear-shaped, salmon-color berry.* This grows along the banks of streams in shady woods of the Coast Mountains. Spring.

b. **D. Hook′eri Benth. & Hook.** *Perianth narrow at base*, with spreading segments. Stamens equaling or surpassing the perianth. Leaves ovate, deeply cordate at base, rough to the touch. *Fruit an orange, obovate berry*, somewhat pubescent. This grows in shady woods, but not close to the water. Spring.

c. **D. trachyan′drum Benth. & Hook.** This is similar to the last, with the stamens shorter than the perianth. *Fruit smooth, with a stout beak.* This grows in the Sierra Nevada Mountains. Spring.

XV. CLINTO′NIA

Stems very short from a rootstock. *Leaves all from the base*, large, oblanceolate, sheathing, with many veins and the veinlets transverse. Flowers solitary or on a scape-like peduncle, in umbels or whorls. *Perianth of 6 oblanceolate divisions, soon falling to pieces.* Stamens on the segments of the perianth with thread-like filaments and versatile anthers. Ovary sessile, 2–3-celled. *Fruit a beautiful blue berry*, smooth and glossy. Seeds few to many.

a. **C. uniflo′ra Kunth.** Covered more or less with woolly hairs. Stem above ground scarcely any. Leaves 4–8 in. long, 1–2 in. broad, narrowed at base. *Peduncle shorter than the leaves, bearing 1, or rarely 2, white flowers, erect, nearly an inch across.* This beautiful and delicate flower grows in the woods and is found from northern California to British Columbia. It blooms in late spring or summer.

b. **C. Andrewsia′na Torr.** Almost smooth. Stem 2–6 in. long, bearing 5 or 6 large leaves nearly a foot long and 2–4 in. wide, bright green and very luxuriant, forming a circular bunch around the tall scape, which is a foot or two high. *Flowers generally many, in umbels or whorled fascicles, deep rose-color, pendent.* Perianth broad at base, $\frac{1}{3}$–$\frac{1}{2}$ in. long. This is found in the redwood groves and is in bloom in early summer. It is one of the most conspicuous plants, whether in fruit or flower or with only its tropical-looking leaves.

XVI. STREP′TOPUS, Twisted Stalk

Stems from slender, creeping rootstocks, leafy, glaucous, branching in pairs. Leaves alternate, sessile, lance-shaped, veinlets transverse. *Flowers usually solitary from the leaf* *axils, on slender, simple or forked peduncles, bell-shaped, greenish white, with the divisions recurved at tip.* Fruit a round berry with 3 cells and many seeds.

S. amplexifo′lius DC. Stems 2–3 ft. high. Leaves heart-shaped at base, 2–5 in. long, rough on the margins. Perianth about half an inch long. This is found in damp, shady places from northern California to Washington. It blooms in the spring.

XVII. TRIL′LIUM, Wake Robin

Stems erect, *naked up to the three leaves which are in a whorl under the flower.* Leaves netted-veined, large and broad. Perianth withering, but not falling. Outer divisions (sepals) greenish, inner (petals) colored. Filaments short. Anthers long, erect. Stigmas sessile on the sessile ovary.

a. **T. ses′sile L.** Leaves broad, round-ovate, often mottled with reddish brown, crowded. *Flowers and leaves sessile.* Petals white, rose-color, deep wine-color, or greenish yellow. This is common in woods near the coast. It is exceedingly variable in the size and shape of the leaves and parts and color of the flowers.

b. **T. ova′tum Pursh.** Leaves on short petioles, ovate, acute or pointed. *Flowers on a peduncle from 1 to 3 in. long.* Petals white, turning rose-color as they fade. This has the same range as the preceding, but is usually earlier and less common.

c. **T. petiola′tum Pursh.** Stem short. *Leaves ovate to kidney-shaped, with petioles equaling or longer than the blade.* Flowers sessile. Petals narrowly oblanceolate, a little longer than the sepals, dull purple. This is found through Oregon and Washington.

AMARYLLIDA′CEÆ. Century Plant Family

Mostly smooth perennial herbs, sending up from the root a scape and leaves which show no distinction between petiole and blade. *Stamens 6. Tube of the 6-parted perianth adnate to the 3-celled ovary.* Capsule 3-celled, several or many seeded. The Chinese Sacred Lily, the Narcissus, Jonquil, and Daffodils belong to this family.

I. AGA′VE, Century Plant, American Aloe

Plants with large, thick, spiny-pointed and spiny-toothed leaves. The flowers are numerous on short bracted pedicels, in spikes or panicles, at the summit of a tall woody scape clothed with bracts. The perianth is thick and fleshy, tubular or bell-shaped, with the 6 divisions nearly equal. Filaments bent in the bud, but becoming straight and extending beyond the perianth. Capsule leathery, with numerous flattened black seeds. Different species of Century Plants are common in cultivation, and several species are native in desert regions. It blooms in California when 10 to 20 years old. "Pulque," a Mexican drink, is made from the sap of some species.

II. NARCIS′SUS, Narcissus, Jonquil

Flowers with a cup-shaped crown at the throat of the perianth. Tube of the perianth somewhat cylindrical, the 6 divisions of the border widely spreading. Stamens 6, inserted in the tube. Scapes with 1 to several flowers from a thin, dry spathe.

N. Tazet′ta. CHINESE SACRED LILY. Flowers white, with yellow cup; fragrant. Leaves and scapes from a large bulb, like an onion. This is cultivated especially by the Chinese and usually grows in water. It is in bloom during the winter, about the time of the Chinese New Year, and can readily be obtained for class study.

IRIDA′CEÆ. IRIS FAMILY

Herbs with equitant 2-ranked leaves. Flowers showy, perfect. *Tube of the perianth attached to the ovary, which is enclosed by spathe-like bracts. Stamens 3, with anthers turned outwards.* Style 1, stigmas 3, often petal-like. Capsule 3-celled and many-seeded.

I. I′RIS, Blue Flag, Fleur de Lis, Flower de Luce

Sepals 3, turned backwards, larger than the 3 erect petals. Stamens 3, distinct, borne on the sepals. Anthers long, and covered by the petal-like branches of the style. Perennials with dagger-shaped leaves and large rootstocks.

a. **I. macrosi'phon Torr.** Stems low, forming mats of bright green, narrow, erect leaves, amid which the flowers arise, overtopped by the leaves. *Perianth with a slender tube from 1 to 4 in. long*, easily breaking. Flowers dark blue, rarely cream-color.

b. **I. Douglasia'na Herbert.** Taller than the last, but also growing in mats. Leaves dark green, rose-color at base, laxly spreading. Stems bent about the middle. *Tube of the perianth slender, an inch or more long.* Flowers variable in color; cream, rose-color, violet, and purplish blue. This is the most widely distributed species.

c. **I. longipet'ala Herbert.** Stems stout, more than a foot high. Leaves glaucous. Flowers larger than the preceding. *Perianth funnel-form at base, sessile on the ovary.* Sepals from 2 to 3 in. long, beautifully veined with yellow and violet. Petals shorter. Petal-like branches of the style with broad crests. This Iris covers acres of ground in low places near San Francisco.

d. **I. Missourien'sis.** Stems slender, the few leaves shorter than the stem. *Bracts papery, dilated.* Flowers blue, generally 2 in a spathe. Sepals and petals 2 or 3 in. long, with narrow claws. This grows in moist or wet places and is widely distributed. It blooms in spring.

II. SISYRIN'CHIUM, Blue-eyed Grass, Star-eyed Grass

Perianth 6-parted, with the spreading divisions all alike. Stamens monadelphous. Stigmas 3-cleft, very slender, usually twisted together. These are small grass-like perennials, with pretty flowers that soon wither, borne on slender scapes.

a. **S. bel'lum Watson.** BLUE-EYED GRASS. Stems usually about a foot high. Leaves shorter. Spathes 2, nearly equal, enveloping the flowers in bud. *Flowers 4–7, purplish blue*, yellow at the center. Divisions 3-toothed or tipped with a point. *Stamens with the filaments united to the anthers.* Stigmas short, hardly apparent. Capsule globular. This is common in damp places.

b. **S. grandiflo'rum Dougl.** Scapes about a foot high. Spathe with 1–4 flowers, flattened but not winged, surpassing the leaves. Bracts broad, unequal, the larger exceeding the flowers. Perianth an inch and a half across, *reddish purple*, occasionally white. *Filaments united only at the broad base.* Style merely cleft at apex. This most beautiful species ranges from northern California to British Columbia.

c. **S. Califor'nicum Ait.** STAR-EYED GRASS, GOLDEN-EYED GRASS. Scape winged, a foot or more high, longer than the leaves. Flowers from 3 to 7, *yellow, nearly an inch in diameter.* Spathe 1. Filaments united at base only. Style divided to the middle. Capsule oblong. *This stains the paper purple when it is pressed.* It grows in swampy places near the ocean.

ORCHIDA'CEÆ. Orchis Family

Perennials, with perfect flowers of peculiar shapes, perianth of 6 divisions adnate to the 1-celled ovary, which contains an immense number of ovules. The stamens are 1 or 2, united with the pistil. The pollen is of a few waxy grains, held together by cobweb-like threads. The family is difficult, and the specimens are so rare that they should not be collected in large numbers for class study. The most familiar genera are *Cypripe'dium*, Lady's Slipper; *Spiran'thes*, Ladies' Tresses; *Habena'ria*; and *Epipac'tis*.

SUBCLASS II. — DICOTYLED'ONOUS PLANTS

Stems composed of bark, wood, and pith; in woody stems which live over from year to year, the wood is generally in annual rings, traversed at right angles by medullary rays. Leaves netted-veined. Cotyledons 2 (rarely more).

Division I

APETALOUS PLANTS. FLOWERS WITHOUT A COROLLA, OFTEN WITHOUT A CALYX. CALYX OFTEN COLORED LIKE A COROLLA.

PIPERA'CEÆ. Yerba Mansa Family

Perennial herbs with jointed or scape-like stems. Leaves entire, with petioles dilated at base, and without stipules. Flowers perfect, without perianth, in dense terminal spikes, with a bract under each flower. Stigmas 1–5, stamens 3–6 or more.

HOUTTUY'NIA (ANEMOP'SIS), Yerba Mansa

Herbs with aromatic, creeping rootstocks, and most of the leaves radical. Flowers in spikes, subtended by a corolla-like involucre on a few-leaved stem. Sepals and petals none, a petal-like bract under each flower. Stamens on the base of the ovary. Ovaries, sunk in the fleshy axis of the spike, each consisting of several follicles, which open and appear to form a 1-celled pod with several parietal placentæ; when ripe, opening at the apex, leaving the old spikes full of regularly arranged holes.

H. Califor'nica Benth. & Hook. YERBA MANSA. This grows in saline or alkaline swamps, and has reputed medicinal value.

MYRICA'CEÆ. WAX-MYRTLE FAMILY

Monœcious or diœcious trees or shrubs. Leaves fragrant, alternate. Flowers in short sessile catkins with one naked flower under each scale. Staminate flowers of about 10 stamens with united filaments. Ovary 1-celled, 1-ovuled, with 2 sessile thread-like stigmas. Fruit a small, round, dark purple nut, unevenly coated on the rough surface with grayish white wax.

Myri'ca Califor'nica Cham. Flowers usually androgynous. Leaves evergreen, leathery, oblanceolate, dark green and glossy above, somewhat whitened below, serrate above the base, and narrowed to a short petiole. Catkins solitary or in thick clusters. From Monterey to Washington in moist places.

SALICA'CEÆ. WILLOW FAMILY

Diœcious trees or shrubs. Flowers in catkins (*f.* Fig. 131; *e.* Figs. 108, 121), destitute of perianth. Fruit a 1-celled pod with numerous seeds, provided with rather long and silky down (usually called cotton), by means of which they are transported by the wind.

I. SA′LIX, Willow

Trees or shrubs, growing near water. *Leaves generally long and pointed;* with stipules generally present on young shoots, disappearing from the older leaves. Stamens 1–6 to each scale of the staminate catkin. On the pistillate catkin the pods are small, ovate, pointed, splitting from the top into two pieces. In bud the catkins are covered with scales that fall off. (The following species generally occur as trees, sometimes also as shrubs.)

a. **S. ni′gra Marsh.** BLACK WILLOW. *Trunk nearly black, generally leaning over the water.* Leaves narrowly lanceolate, long-pointed, closely serrate, smooth and light green on both sides. Catkins on leafy branchlets. Pods brownish on short pedicels. *Stamens 3–5 to each scale.* Along the San Joaquin and Sacramento Rivers.

b. **S. læviga′ta Bebb.** *Trunk straight, with dark brown bark.* Leaves rather thick, glossy green above, glaucous beneath. Scales of the catkin toothed. Otherwise much like the preceding, but with broader leaves. Widely distributed.

c. **S. lasiol′epis Benth.** Trunk generally straight, with grayish brown bark, almost smooth. Leaves thick, oblanceolate, unequally serrate, glaucous and brown-hairy beneath. *The young leaves are closely covered with silky hairs.* Catkins on very short peduncles; scales dark brown, densely covered with white hairs. *Stamens 2 to each scale, with the filaments united at the base.* Pods on short pedicels. This is the most common willow and varies considerably. Widely distributed.

d. **S. Scouleria′na Barratt (S. flaves′cens Nutt.).** Small tree or shrub. Leaves silky tomentose on the underside when young, obovate or oblanceolate. *Catkins short, sessile, appearing before the leaves,* densely flowered. *Stamens 2 to each scale of the catkin;* scales covered with long silky hairs. Capsules tomentose on short pedicels. Styles wanting; stigmas long, entire or deeply parted. The freshly broken twigs of this species have a strong and disagreeable odor. It is one of the earliest willows in bloom and is very lovely and conspicuous when in bloom. It is found from Santa Barbara to Alaska.

e. **S. Sitchen′sis Sanson.** Similar to the above but with leaves much more tomentose, with permanent and shining tomentum. *Catkins long, appearing before the leaves but often in the axils of the previous season's persistent leaves. Stamens 1–2 to each scale of the catkin;* scales villous and catkins tomentose. This is a beautiful willow with large broad leaves. It is found from Santa Barbara to Alaska.

f. **S. corda'ta Muhl.** Small tree or shrub. Leaves oblong lanceolate, heart-shaped or acute at base, pointed at apex, serrate, smooth except when young. *Catkins leafy at base, cylindrical, lengthening in fruit. Stamens 2 to each scale of the catkin.* Scales dark but villous with long white hairs. Capsule smooth. Style short, stigma bifid. This is found on the eastern slope of the Sierra Nevada Mountains. Northward.

g. **S. fluvia'tilis (S. longifo'lia).** NARROW-LEAVED WILLOW. A shrub forming dense clumps. *Leaves linear to lanceolate, tapering at apex and base, sessile, 2–4 in. long and $\frac{1}{4}$ in. or less wide;* margin entire or with scattered teeth. *Catkins on leafy branchlets.* Stamens 2 to each scale. Capsules downy or smooth, on short pedicels, with large, sessile stigmas. Sometimes the leaves are smooth, sometimes white downy. This is widely distributed and variable.

II. POP'ULUS, Cottonwood, Poplar, Aspen

Trees with broad ovate or deltoid leaves, and buds covered with scales full of aromatic balsam. Staminate catkins appearing before the leaves, with many stamens to each scale, on a cup-shaped disk; anthers purple, staining the ground where they fall. *Fertile catkins of round or ovate pods on slender pedicels.*

a. **P. trichocar'pa Torr.** BALM OF GILEAD, BALSAM COTTONWOOD. *Leaves ovate, pointed, cordate or rounded at base, crenate, dark green above, greenish brown beneath, on terete petioles.* Buds full of balsam, and very fragrant. Tree with cracked bark and open growth. Widely distributed.

b. **P. Fremon'ti Watson.** Leaves *broadly deltoid,* with few rounded teeth on the margins, *bright green on both sides; petioles flattened.* Large tree, with gray, cracked bark. Widely distributed.

c. **P. tremuloi'des Michx.** ASPEN, QUAKING ASP. Trunk straight, slender, with smooth grayish white bark. *Leaves round-ovate, thin, on slender petioles flattened at right angles to the broad surfaces of the leaf, causing it to sway edgewise with the least perceptible breeze.* In the Sierra Nevada Mountains and far northward.

BETULA'CEÆ. BIRCH AND ALDER FAMILY

Monœcious trees or shrubs, growing along streams. Leaves toothed. Staminate catkins drooping; when young covered with resin, but without bud-scales. Stamens 2–4 in a 4-lobed or scale-like perianth under the bracts of the catkin. Pistillate flowers in short, erect cones. Pistil with a 2-celled ovary and 2 stigmas.

I. AL′NUS, Alder

Trees or shrubs with broad, toothed leaves. Staminate catkins long and drooping, appearing in early spring. Pistillate catkins erect, becoming dark brown and woody, *persisting on the trees for some time after the seeds have fallen.* Stamens generally 4 in each perianth.

a. **A. rhombifo′lia Nutt.** *Trees with dark brown bark.* Leaves ovate or oval, paler beneath, *irregularly glandular-toothed.* This blooms very early, the staminate catkins falling in January or February, and the fruit ripe at the same time. Widely distributed.

b. **A. rub′ra Bong (A. Orego′na Nutt).** *Bark pale gray, mottled with darker gray.* Leaves ovate or elliptical, rusty-pubescent on the lower surface, *doubly serrate, with revolute margins to the teeth.* Twigs smooth, winter buds glutinous, nearly ½ in. long. Catkins open in the spring before the leaves. From San Francisco to Alaska.

c. **A. tenuifo′lia Nutt.** A small tree with red-brown bark, often forming thickets. Twigs pubescent. Leaves ovate rounded or cordate at base, *doubly serrate with teeth acute,* veins prominent, winter buds short, obtuse, pubescent, about ⅓ in. long. In the Sierra Nevada Mountains and northward, especially on the eastern slope of the mountains.

II. BET′ULA, Birch

Trees or shrubs with smooth bark often coming off in sheets, dotted on the branches. Catkins similar to those of Alnus, but *the fertile ones do not persist on the trees after the seeds are ripe.* The scales and seeds fall away from the axis. Each scale of the staminate catkins bears 3 flowers, each of which consists mainly of two 2-parted filaments with an anther cell on each. On every scale of the pistillate catkins are borne 2–3 flowers, each of which consists simply of a naked ovary with 2 diverging stigmas.

B. occidenta′lis. Black Birch. A tree 20–30 ft. high with smooth dark brown or reddish bark, with conspicuous whitish horizontal lenticels, becoming lighter in color with age ; the branchlets dotted with resinous spots. Leaves thin, broadly ovate, serrate with glandular teeth. Seeds with wings as broad as the body. Bracts of the catkin 3-lobed. Most common on the western side of the Rocky Mountains.

CUPULIFERÆ. Oak Family

Monœcious trees or shrubs. Staminate flowers in catkins; pistillate forming, in fruit, a nut in a cup-like or bur-like involucre.

I. QUER′CUS, Oak

Staminate flowers in slender, fringe-like catkins, with a 6-lobed perianth; pistillate usually single, consisting of a 3-celled ovary enclosed in a bud-like involucre which becomes a cup. Stigmas 3. *Only 1 of the ovules ripens to form an acorn;* the other 5 can be seen as rudiments.

a. **Q. loba′ta Nee.** Valley Oak, Roble, White Oak, Weeping Oak. Leaves large, deciduous, deeply lobed with *obtuse divisions*, 3–4 in. long on stout petioles. Cup deep, with a rough warty surface, *acorns 1–3 in. long, usually pointed.* These trees grow to a great size, and are generally isolated in fertile valleys. They have graceful, drooping branches. Throughout California.

b. **Q. Garrya′na Dougl.** A large tree, often 10–12 ft. in circumference, with bark only 1 or, at most, 2 in. thick. *Leaves thick, strongly veined*, 4–6 in. long, 2–5 in. wide, *with coarse lobes, obtuse or acute, entire or again lobed*, dull green on the upper side, pale green or yellowish on the lower, turning brown or red in the fall. Acorns sessile or on short peduncles, with the *nut oval and obtuse*, about 1½ in. long, *in small, shallow cups.* The winter buds of this oak are nearly half an inch long and are *densely tomentose.* It is found in the valleys and hills north of San Francisco Bay and extends to British Columbia. It is common in Oregon and Washington.

c. **Q. Douglas′ii Hook. & Arn.** Blue Oak, White Oak. Leaves an inch or two long, deciduous, oblong, with shallow lobes, *bluish green, veiny. Cup usually shallow, with flat scales;* acorns oblong, often swollen in the middle. *Bark usually light gray*, causing the trunks to be very noticeable on hillsides. From Tehachapi to the Sacramento Valley.

d. **Q. oblongifo′lia Torr.** Evergreen Live Oak or White Oak of southern California. *Leaves evergreen, oblong, often entire*, or with a few blunt teeth, thick, with *the veining almost concealed.* Cup with warty surface, acorns oblong. Not found north of Tehachapi.

e. **Q. chrysol′epis Liebm.** DROOPING LIVE OAK, GOLDEN CUP OAK. Leaves evergreen, oblong, entire or spinosely toothed, often both kinds on the same branch, *dark green on the upper surface, covered with a golden powder on the lower surface of young leaves; the old leaves becoming smooth and paler beneath.* Cup either bowl or saucer shaped, more or less covered with yellow powder, sometimes so dense as to conceal the scales of the cup. Acorns large and thick. This is a shrub or an immense tree growing usually in cañons. It is extremely variable in leaves and fruit. Throughout California.

f. **Q. agrifo′lia Nee.** LIVE OAK, ENCINO. Leaves evergreen, *spiny-toothed on the margin, which is curled under. Pubescence stellate.* Staminate flowers very numerous. Cup bowl-shaped, glossy, of flat scales; acorns slender, tapering, maturing in one year. This is a round, compact tree, or it sprawls over the ground with low branches, widely spreading. This never grows far from the sea, but keeps within the fog-line.

g. **Q. Wislize′ni A. DC.** POST OAK, LIVE OAK. Leaves evergreen, dark, glossy, spiny-toothed, *but not curled back, very stiff, smooth on both sides when old. Acorns maturing in 2 years.* Cup deep, very rough-scaly. Acorns variable, often almost covered by the cup. This is usually a tree, but is often shrubby and is found throughout California.

h. **Q. Califor′nica Cooper (Q. Kelloggii).** KELLOGG'S OAK, BLACK OAK. Leaves deciduous, large, *deeply lobed with pointed divisions, smooth and glossy green when old.* Fruit on short stems. Cups deep with smooth scales; acorns large, oblong, obtuse. Bark black and rough. The young shoots are rose-color and densely tomentose. Through the mountains of California.

i. **Q. densiflo′ra Hook & Arn.** CHESTNUT OAK, TANBARK OAK. *Leaves evergreen, oblong, ribbed with thick veins, toothed, covered more or less with white tomentum.* Cups saucer-shaped, densely covered with long, linear, curved scales that give the cup a *bristly appearance;* acorns large, with a thick shell. This is in flower and fruit at the same time, generally blooms in summer, and has *large panicled spikes of androgynous flowers.* From the Tehachapi Range northward.

II. CASTANOP′SIS, Western Chinquapin

Flowers androgynous in erect axillary or terminal panicled spikes. Staminate flowers with perianth 5–6-lobed, and stamens twice as many; sessile on the upper part of the spikes. Pistillate flowers below, in a scaly involucre. *Ovary 3-celled, with 2 ovules in each cell, maturing only 1–3 nuts in a roundish involucre, densely covered with brown, intricately* *branched prickles.* This blooms chiefly in the summer and fall, and is generally fruiting at the same time.

a. **C. chrysophyl'la A. DC.** GOLDEN-LEAVED CHINQUAPIN. Leaves *lanceolate, pointed,* dark green above, golden below. This is generally a shrub, but becomes a large beautiful tree in Mendocino County.

b. **C. semper'virens Dudley.** Leaves *obovate-oblong, obtuse at apex.* This is the species of the Sierra Nevada Mountains.

III. COR'YLUS, Hazelnut

Staminate flowers in slender, drooping catkins, each flower consisting of 8 stamens with 1-celled anthers. Pistillate flowers several, grouped in a scaly bud, each consisting of a single ovary in the axil of a bract, and with a smaller bract on each side. Ovary 2-celled, 2-ovuled (one seed only maturing). Stigmas 2, bright red, long and slender. *Nut roundish, enclosed in a fringed cup.*

C. rostra'ta Ait. var. Califor'nica A. DC. Shrubby. Leaves slightly heart-shaped. Staminate flowers drooping, very numerous; conspicuous on the leafless stems of winter. Involucre completely covering the nut, and prolonged into a beak above it. This is common in the woods along the coast. It blooms very early.

ARISTOLOCHIA'CEÆ. DUTCHMAN'S PIPE FAMILY

Shrubs or perennial herbs. Leaves heart or kidney shaped, palmately veined. Perianth adnate to the 6-celled ovary, greenish brown, regular or irregular. Stamens 6–12, attached to the style, with anthers opening outwards. Styles 6, united at base.

I. AS'ARUM, Wild Ginger

Low herbs. Leaves and flowers springing from creeping rootstocks which have the odor of ginger. Leaves large, kidney-shaped, on long petioles. *Flowers erect, bell-shaped, with 3 divisions bearing long tails.* Stamens 12, almost free from the style. Capsule round. Seeds large, 2 rows in each cell.

a. **A. cauda'tum Lindl.** Flowers on slender pedicels. Divisions of the perianth with tails from 1 to 3 in. long. This grows in damp, shady places under the trees in the Coast Mountains.

b. **A. Hartwe′gi.** Flowers on stout peduncles, from a woody base. Divisions of the perianth narrowed to a linear apex. Leaves marked with lighter-colored veins, often white-veined. This grows in the higher parts of the Sierra Nevada Mountains under the trees.

II. ARISTOLO′CHIA, Dutchman's Pipe

Perianth something like a pipe in shape, inflated, soon deciduous from the inferior ovary. Anthers 6, sessile, adnate to the short style. Stigmas 3–6-lobed. Pod club-shaped.

A. Califor′nica Torr. A shrubby vine with twining stems. Flowers greenish brown with purplish brown stripes and markings, appearing before or with the leaves, in the leaf axils. Peduncles slender, with a leaf-like bract in the middle. Leaves soft, pubescent, ovate-cordate on short petioles. This climbs amid the brush, from which it is not readily distinguishable, as the colors of the flower are so similar to its surroundings, and usually there are no leaves when the flowers are in bloom.

POLYGONA′CEÆ. Buckwheat Family

Shrubs or herbs. Perianth small, generally corolla-like, of 3–6 distinct or united divisions. Stamens 4–9 on the perianth. Ovary a 3-sided or lens-shaped akene, generally dark brown or black. Styles 2–4.

I. ERIOG′ONUM, California Buckwheat

Flowers small, perfect, on hair-like pedicels from *bell-shaped or top-shaped involucres.* Perianth of 6 petal-like divisions, thin in texture, yellow, white, or rose-color. Stamens 9. Styles 3, generally deflexed or curled, with cap-like stigmas. Akenes 3-sided (rarely lens-shaped or winged). Leaves without sheaths or stipules, often more or less white-woolly, generally in a spreading cluster at the base of the stem. The small involucres full of flowers are variously clustered in umbels, panicles, racemes, etc.

These plants inhabit dry places. The species are very numerous, and difficult to distinguish. The majority of the species are annuals, much branched, with slender stems. The perennial species are stouter, and one, *E. fascicula'tum,* is an evergreen shrub, with small, short leaves in clusters along the stems, and the flowers in terminal cymose panicles.

II. CHORIZAN′THE, Turkish Rugging

Involucres sessile, tubular, thick in texture, 3–6-ribbed, with as many teeth or divisions, *tipped with stiff bristles.* Flowers small, 1–3, included in the involucres, often nearly sessile. Stamens generally 9. Ovary smooth and akene triangular. Low, much branched annual herbs with slender branches, very brittle when dry. The leaves are all in a cluster at the base, and the bracts are ternate and usually small. They grow in dry, sandy places, where they often cover the ground as with a veil. The species are numerous, generally local and difficult to distinguish.

III. RUMEX, Dock, Sorrel

Coarse herbs, generally perennial, with acid or bitter juice. Perianth with 3 outer divisions green, the 3 inner generally larger, reddish or yellowish green, becoming large and veiny, often *with a white grain on the back of one or all of the inner divisions,* which closely cover the 3-sided akene. Styles 3. *Stigmas with a tuft of hairs at the top.* Leaves with papery stipules sheathing the stem.

a. **R. acetosel′la L.** Sorrel, Sour Grass. *Flowers diœcious,* small, in a narrow panicle, becoming reddish. The inner divisions of the perianth do not enlarge over the akene. *Leaves thick, hastate.* This is very common, spreading by slender rootstocks. The male plants greatly exceed the female in number. Common everywhere.

b. **R. salicifo′lius Wein.** Willow-leaved Dock. Stems several, generally spreading and ascending or erect. Leaves light green, 3–6 in. long, lanceolate, narrowed to a short petiole. Flowers in a leafy panicle, which becomes dark red as it grows old. *Each of the inner divisions of the perianth has a large grain on the outside.* Common in moist places everywhere.

c. **R. cris′pus L.** Curly Dock. Leaves on long stalks with a *crisped or curled margin.* Flowers in a leafy panicle. *The grains are present on all the inner divisions of the perianth.* Common.

d. **R. pul′cher L.** *Branches widely spreading, leafy,* reddish when young, becoming brown and stiff when old. Leaves rough on the lower surface, generally lanceolate and acute. Flowers in numerous whorls at short intervals along the branches. *Perianth with the inner divisions all grain-bearing and with 4–6 stiff bristly teeth on each side.* This is an introduced weed, becoming very common.

e. **R. occidenta′lis Watson.** Tall, 3–6 ft. in height. Lowest leaves with blade often a foot long and petiole almost as long, ovate to oblong-lanceolate, with the base heart-shaped. Panicle large, almost destitute of leaves. Perianth with large reddish divisions, finely toothed near the cordate base, *without grains on the back.* This grows in wet places throughout the Pacific coast and blooms in summer.

f. **R. persicarioi′des L.** Annual, generally with many stems, low, erect, or spreading. Leaves linear-lanceolate, on short petioles. Flowers in *dense whorls at nearly all the leaf axils.* Divisions of the perianth *all bearing grains and with 2–3 long, slender, awn-like teeth on each.* This is found in wet places, generally along the edges of ponds and lakes. It is widely distributed and blooms in summer.

IV. POLYG′ONUM, Jointweed, Smartweed

Flowers perfect in axillary or panicled spikes. Perianth of 5–6 petal-like divisions, often rose-color, not enlarging in fruit. Stamens 4–9. *Styles 2–3, with cap-like stigmas. At the base of the petiole there are papery sheaths around the stem.* The species are difficult to determine. They generally grow in swampy places.

CHENOPODIA′CEÆ. Pigweed Family

Shrubs or herbs, often with fleshy stems and leaves, usually found near the ocean or in alkaline soil, often covered with white scurf. Leaves generally salty or bitterish. Flowers perfect, monœcious or diœcious. Perianth small, of 5 greenish sepals. Stamens as many as the sepals, and opposite them. Ovary 1-celled, with the embryo coiled in a ring or spiral around the endosperm.

I. CHENOPO′DIUM

Flowers perfect in axillary or terminal clusters. *Perianth nearly covering the fruit, which is round and flattened.* Leaves alternate on petioles, often covered with scurf or down.

a. **C. al′bum L.** LAMB'S-QUARTER, PIGWEED. Annual, erect, simple or branched. *Leaves cold to the touch, covered with a flour-like powder*, from lanceolate to ovate, wavy and toothed. Flowers in spikes, either simple or panicled, and axillary or terminal. This is common in cultivated ground.

b. **C. Califor′nicum Watson.** SOAP PLANT. Perennial, from a spindle-shaped root. Stems smooth, usually several from the root, spreading and ascending. *Leaves triangular, 2–3 in. long, sharply and irregularly toothed.* Flowers densely clustered in long, slender, terminal spikes. Seed large, vertical, only partly covered by the 5-toothed, bell-shaped perianth. This blooms in spring, often under bushes. Near the coast, from San Diego to San Francisco Bay.

c. **C. mura′le L.** Stems generally reddish, with some flour-like powder, branching rather closely, forming a compact plant, a foot or two high. *Leaves broadly triangular to lanceolate, coarsely and deeply sinuate-toothed.* Flowers generally in *small clusters in the leaf axils, shorter than the leaves.* Sometimes the clusters are panicled at the top of the stems. Seeds black with sharp edges. Common everywhere.

d. **C. ambrosioi′des L.** WORMSEED. Stems annual, stout, and branching, 2–3 ft. high. *Leaves lance-shaped, 2–5 in. long, sinuate-dentate, on short petioles.* Flowers in axillary spikes, or in panicled leafless spikes. The entire plant has a *strong, persistent, aromatic odor.* It is common in salt and alkaline marshes.

II. AT′RIPLEX, Salty Sage

Herbs or shrubs, mealy, scurfy or pubescent. Flowers in simple or panicled spikes, or clustered in the axils. Staminate flowers with the divisions of the perianth 3–5, and stamens opposite the divisions. *Pistillate flowers enclosed by 2 bracts, which are distinct or united, variously toothed, or with wart-like protuberances or winged, often thickened. Seed vertical,* generally falling with the bracts which enclose it.

a. **A. Califor′nica Moquin.** Stems many from the base, spreading on the ground a foot or more, densely mealy. *Leaves sessile, small, lanceolate, the lower opposite.* Flowers monœcious in small, axillary clusters, the staminate ones mostly near the top of the cluster. *Fruiting bracts small, round, spongy, not toothed, and without wart-like protuberances.* This is found along the coast.

b. **C. canes′cens James.** BUCKWHEAT SAGE, SALTY SAGE. Shrubby, diœcious. Leaves grayish green, linear or oblanceolate. Flowers in panicled spikes. *Fruiting bracts with 4 distinct dilated* *wings.* This is found in the interior, in alkaline valleys. It is a valuable forage plant.

(The species of *Atriplex* are numerous and difficult, also somewhat local, so the rest will be omitted.)

AMARANTA′CEÆ. Amaranth Family

Herbs, with small papery flowers surrounded with persistent papery bracts. Perianth persistent of from 1 to 5 papery divisions. Stamens as many as the divisions of the perianth, sometimes fewer. Ovary 1-celled and 1-seeded, forming a fruit, which opens like the lid of a box. Seed always vertical. Stigmas 2–3, sessile.

AMARAN′TUS. Amaranth

Flowers generally monœcious. Perianth of from 3 to 5 divisions. Bracts 3 to each flower. Stamens with filaments spreading at base. Stigmas generally 3, forming 3 beaks on the fruit. Seeds brown or black, dropping readily when ripe.

a. **A. retroflex′us L.** Pigweed. *Stems stout, erect.* Leaves ovate, 1–3 in. long, on petioles almost as long. Flowers green, in thick, erect, crowded spikes, either terminal or axillary. Divisions of the perianth 5. A common weed.

b. **A. al′bus L.** Tumbleweed. *Stems light green, branching diffusely from the base, forming a mound-like plant.* Leaves spatulate or obovate, often wavy-margined, on slender petioles. Divisions of the perianth 3, pointed, shorter than the fruit. Bracts awl-shaped with stiff points. This forms a tumbleweed, and will often be found caught in fences and bushes. Common everywhere.

NYCTAGINA′CEÆ. Four-o'clock Family

Herbs with fragile stems and swollen joints. Leaves opposite, entire, unequal at base. Flowers perfect, several in an involucre resembling a calyx. Perianth corolla-like, showy, the base hardening around the 1-seeded ovary.

I. MIRAB'ILIS, Four-o'clock

Involucre 5-lobed. Flowers nearly sessile. Stamens 5. Fruit scarcely ribbed. Herbs with showy, reddish purple flowers, opening in the afternoon.

a. **M. multiflo'ra Gray.** Stems often glandular; stout and spreading. Leaves broad, an inch or two long, ovate, on petioles a half-inch long. Flowers 6 in the involucre. Perianth open-funnel-form, with border an inch in diameter, and tube from 1 to 2 in. long. Southern California.

b. **M. Califor'nica Gray.** Stems several from a woody root, supported on bushes, as if climbing. Leaves ovate, cordate, on short petioles. Involucre small, 1–3-flowered. Perianth open-bell-shaped. Fruit small. This is common in southern California.

II. ABRO'NIA, Sea Verbena

Involucre of from 5 to 15 distinct papery bracts. Flowers sessile, with salver-shaped perianth, having a long tube, and the border with notched segments. Stamens 5, within the tube. Annual or perennial, fleshy herbs, with thick, opposite leaves. Flowers in umbels on long peduncles, fragrant, showy, rose-color, yellow, or white.

a. **A. umbella'ta Lam.** Stems prostrate, viscid. Leaves ovate or oblong, narrowed at base to a petiole. *Perianth rose-color. Fruit winged.* This grows on the seacoast.

b. **A. latifo'lia Esch.** Stems similar to above. Leaves broadly ovate, with kidney-shaped base. *Perianth yellow.* The flowers have the odor of orange blossoms. This is found on the coast from Vancouver to Monterey.

PORTULACA'CEÆ. Portulaca Family

Fleshy herbs. Flowers with 2 sepals (except in *Lewisia*) and 2–5 or more petals. Stamens opposite the petals when of the same number. Ovary 1-celled, style 2–8 cleft. The flowers open only in the sunshine or bright daylight.

I. PORTULA′CA, Purslane

Low herbs with alternate or opposite leaves. Flowers terminal and sessile. Petals 4–6. Stamens 7–30, inserted where the calyx joins the ovary. Pistils with 3–8 styles. *Fruit like a box opening with a lid, full of black seeds.*

P. olera′cea. PURSLANE, PUSLEY. Prostrate. Flowers small. Calyx lobes keeled. Petals yellow, spreading, notched. Common everywhere.

II. LEWIS′IA, Bitter-root

Low herbs, without stems, from thick, perpendicular roots. Leaves forming a rosette at the apex of the root. Flowers large, solitary, on low scapes, conspicuous when open, white or rose-color. Sepals 2–8. Petals 3–16. Stamens numerous. Style branches 3–8. *Pod globose, with thin walls that split from the base upwards.*

L. redivi′va. BITTER-ROOT. Leaves numerous, shorter than the scapes. Scapes jointed above the middle, bearing an involucre of 5–7 papery bracts. The flower when expanded is an inch in diameter, resembling a small cactus blossom. The sepals resemble the petals. The Bitter Root Mountains receive their name from this plant. It is the state flower of Montana.

III. CALANDRIN′IA

Sepals green and persistent. Petals and stamens usually 5, the former sometimes 3–10, the latter often indefinite. *Ovary 3-valved.* Seeds black and shining or rough, *numerous.*

a. **C. Menzie′sii Torr. & Gray.** Flowers crimson or magenta in racemes. *Petals a little longer than the sepals.* Stamens 3–10. Seeds shining. Widely distributed.

b. **C. el′egans Spach.** Stems rather stout, smooth, with ascending branches. Flowers numerous, rose-color. *Petals twice as long as the sepals.* Stamens 10–15. Usually found most abundant in cultivated ground.

IV. MON′TIA, Miner's Lettuce

Petals and stamens 5. *Pod 3-valved and 3-seeded.* Flowers white or rose-color, in racemes or panicles. When the seeds are ripe they are shot out of the pod by the elastic closing of the valves.

a. **M. perfolia'ta Howell.** Miner's Lettuce. Root leaves on long petioles, *stem leaves forming a round perfoliate leaf below the flowering stems.* Flowers small, white, often growing on but one side of the stem. This is very common and widely distributed. It grows in the shade and blooms in spring and early summer.

b. **M. Sibir'ica Howell.** Stems brittle, often climbing over other vegetation and growing in swampy places. *Leaves sessile but not united.* Flowers pink or white, a half inch in diameter, *on long pedicels, in long, loose racemes.* From Marin County to Alaska, blooming in spring and summer.

c. **M. gypsophiloi'des Howell.** Annual, pale green, with many slender stems from the root, 3–10 in. high. Root leaves linear or linear-spatulate, shorter than the stems. *Stem leaves at the base of the panicle partly united on one side. Flowers numerous, pink, sweet-scented.* This blooms in early spring and grows on rocky banks and hills. It is very variable in size and shape of leaves. In the coast mountains of central California.

d. **M. linea'ris Greene.** Annual, 6 in. to a foot high, branching. Leaves almost thread-like, fleshy, an inch or so long, becoming slightly wider toward the apex. *Flowers in racemes on one side of the stem on pedicels that recurve in fruit.* Petals white, tinged with pink, unequal, narrowed at base, separate or somewhat united. Moist places through California and northward, blooming in spring.

e. **M. Chamisso'nis Greene.** Stems erect or procumbent, *propagating by runners that have a round bulblet at the tip.* Leaves oblong-spatulate, in several pairs. *Flowers in racemes, the bracts present only with the lower flowers,* on pedicels that recurve in fruit. Petals rose-color, longer than the calyx. Seeds kidney-shaped, covered all over with tubercles. This is widely distributed and grows in wet places, blooming in spring and summer.

V. SPRA'GUEA, Pussy-paws

Sepals thin and papery. Petals 4. Stamens 3. Style with 2 lobes at the apex. Pod 2-valved. *Flowers densely clustered in umbellate spikes* curling in at the tips.

S. umbella'ta Torr. Stems several, usually from a thick root. Root leaves oblanceolate or spatulate, forming a rosette at the base, stem leaves becoming mere bracts. Flowers light rose-color. Common in the Sierra Nevada Mountains.

CARYOPHYLLA′CEÆ. Pink Family

Herbs with regular flowers, sepals as many as the petals (generally 5, the latter sometimes wanting), stamens as many or twice as many, ovary 1-celled with central placenta, styles 2–5.

I. SILE′NE, Pink

Sepals united into a 5-toothed calyx. Petals with both blade and claw, together with the 10 stamens, attached to the stipe of the ovary. *Styles 3. Capsule dehiscent from the top by 6 teeth.* Leaves opposite, without stipules. Flowers generally showy.

a. **S. Gal′lica L.** Stems generally several. Leaves hairy, spatulate. *Flowers small, on short pedicels in one-sided racemes.* Petals pale rose-color, not much longer than the sepals. This is a common introduced weed.

b. **S. Califor′nica Durand.** Low, glandular herbs, with lax, leafy stems, generally branching above. Flowers few, nearly an inch in diameter, on short pedicels, the lowest of which are deflexed in fruit. *Petals 5, bright scarlet, the blades cut into 2 divisions, which are generally toothed.* Widely distributed in shady places where the ground does not become very dry.

c. **S. lacinia′ta Cav.** Stems ascending, 1–2 ft. high. Leaves narrow, 2–3 in. long. Flowers few on the long branches. *Blades of the petals 4-cleft into linear lobes, scarlet, smaller than the preceding.* Pedicels not deflexed in fruit. This is common in southern California.

d. **S. verecun′da Watson.** Stems several from the rootstocks, branching, leafy, glandular-viscid, especially on the upper part. Leaves lanceolate, spatulate or linear. Flowers 1–3 at the ends of short branchlets. *Petals with blades shorter than the claws, rose-color; blades 2-cleft* and with the appendages in the throat oblong, entire or toothed. This is common in San Francisco near the cemeteries. It is widely distributed in California.

II. CERAS′TIUM, Mouse-ear Chickweed

Sepals separate. Petals 5, white, notched. Stamens 10. *Stigmas 5.* Capsule dehiscent from the top by 10 teeth.

a. **C. arven'se L.** Perennial, with spreading stems. Leaves linear-lanceolate, clasping the stem. *Flowers ½ in. in diameter, on long pedicels, in few-flowered cymes.* Capsule extending but little beyond the calyx. Common around San Francisco and northward.

b. **C. visco'sum L.** Annual, somewhat clammy, branched from the base. Leaves small, generally ovate. Flowers on short pedicels in rather close cymes. *Petals shorter than the calyx. Capsule nearly straight, much longer than the calyx.* The flowers open only in sunshine. This is an introduced weed.

III. STELLA'RIA, Chickweed

This is similar to *Cerastium*, but the *petals are 2-lobed,* and the capsule is globose, dehiscent to below the middle.

a. **S. me'dia L.** Chickweed. Annual, spreading and rooting at the lower joints. Leaves ovate, petioled. *Flowers small, on slender pedicels, which are deflexed in fruit, in the axils of leafy bracts.* Stamens 3–10. Pod equaling or surpassing the calyx. This is introduced, and is very common in shady, damp places.

b. **S. ni'tens Nutt.** Annual, low, with slender, shining stems. Flowers small, erect, on short pedicels. *Sepals shining, 3-nerved, twice as long as the petals, which are sometimes wanting.* Pod shorter than the calyx. This is a delicate little plant, with inconspicuous flowers blooming in early spring and soon disappearing.

c. **S. cris'pa Ch. & Schl.** Smooth, with long, weak, trailing stems. *Leaves thin, ovate, about an inch long, with crisped margins.* Flowers axillary, on slender pedicels. Sepals lanceolate, 3-nerved. Petals small, or wanting, white. Capsule when ripe longer than the sepals. Northern California to Alaska, growing in wet, shady places and blooming in spring and summer.

d. **S. borea'lis Bigel.** Generally smooth and erect, 6–10 in. in height. *Leaves lanceolate, narrowed to a long point, ½–1½ in. long, with one prominent nerve.* Pedicels often deflexed, scattered. Sepals ovate-lanceolate with papery margins, acute or obtuse. Petals shorter than sepals or wanting. Pods narrow, acute, nearly twice as long as the sepals. Seeds smooth. Northern California to Washington. Blooming in summer.

IV. ARENA'RIA, Sandwort

Sepals separate. *Petals 5, white, entire or notched.* Stamens 10. *Styles 3. Pod splitting into 3 valves, each with 2 parts.*

a. **A. Douglas'ii Torr. & Gray.** Slender, low, much-branched annuals. Leaves very narrow, thread-like. Flowers $\frac{1}{4}$ in. in diameter, on long, slender pedicels. Pod globose, equaling the calyx. *Seeds flat, smooth.* Throughout California.

b. **A. Califor'nica Brewer.** Similar to the preceding, but with lanceolate, very short, obtuse leaves, flowers half as large, capsule oblong, *seeds small and rough, with minute points.* Throughout California.

V. SPER'GULA, Corn Spurry

Sepals separate. Petals 5, entire. Stamens 10. *Styles 5,* alternating with the sepals. *Capsule 5-valved,* with valves opposite the sepals.

S. arven'sis L. Annual, branching herbs, with fleshy, thread-like leaves in whorls. Flowers small, white, on long pedicels that become reflexed. Sepals as long as the petals and a little shorter than the capsule. This is a common weed, blooming more or less throughout the year.

VI. SPERGULA'RIA (TISSA, BUDA, LEPIGONUM), Sand Spurry

Sepals separate. Petals 5. Stamens 10. Styles 3–5. *Capsule 3-valved.* Leaves usually fleshy, with papery stipules. Flowers white or rose-color. Low herbs, usually growing near the coast or on alkaline soil.

S. macrothe'ca Robinson. Perennial, much branched from the base, rather stout. Flowers white or rose-color, nearly $\frac{1}{2}$ in. in diameter, on pedicels that become nodding. Capsule slightly surpassing the calyx. Seeds smooth with a narrow wing. The large ovate stipules are quite noticeable. In salt marshes from Marin County to San Diego.

ILLECEBRA'CEÆ

This family is similar to *Caryophyllaceæ,* and is included under the latter by some botanists. It has an undivided or 2-cleft style, a 1-seeded fruit (like an akene), and the petals wanting or minute.

PENTACÆ'NA, Sand Mat

Sepals 5, hooded, terminating in a spine. Petals scale-like. Stamens 3–5 at the base of the sepals. Calyx becoming closed over the fruit.

P. polycnemoi'des Bartl. Perennial herbs, forming mats of densely flowered lax stems. Leaves very small, tipped with sharp awns that become recurved. Stipules papery, shorter than the leaves, but very noticeable. Flowers small, greenish, sessile, clustered in the axils. This grows in sandy soil and is common along the seacoast.

RANUNCULA'CEÆ, Buttercup Family

Herbs (Clematis shrubby) with a colorless, acrid juice, distasteful to animals. Parts of the flower all separate and distinct, inserted on the receptacle. Petals often wanting or peculiar in form. Stamens numerous; fruit consisting of numerous akenes (*f.* Fig. 166; *e.* Fig. 169), of several follicles (*f.* Fig. 168; *e.* Fig. 171), or sometimes of berries. Leaves without stipules, often clasping at base (*f.* Fig. 97; *e.* Fig. 70), generally much cut or divided.

I. CLEM'ATIS, Virgin's Bower

Climbing over bushes or rocks by the leafstalks of the compound, opposite leaves, or sometimes erect and not climbing. *Sepals 4, petal-like. Petals none or very small.* Pistils numerous, forming a round bunch of akenes with styles developing into long feathery tails.

a. **C. ligusticifo'lia Nutt.** *Flowers diœcious, in panicles.* Sepals thick, dull white, less than ½ in. long. Akenes with tails from 1–2 in. long. Widely distributed.

b. **C. lasian'tha Nutt.** *Flowers diœcious, solitary, on stout peduncles with one or two bracts.* Sepals thick, dull white, sometimes nearly an inch long. Fruit similar to above. In the Coast and Sierra Nevada Mountains.

c. **C. Douglas'ii Hook.** Bushy Clematis. *Stems erect, a foot or two high, not climbing.* Leaves once, twice, or thrice pinnately compound, with linear or lanceolate leaflets, axils woolly. Flowers perfect, usually solitary and terminal, nodding. *Sepals leathery, dark* *blue, forming a bell-shaped flower,* more than an inch long, with spreading tips. Tails to the akenes conspicuous. This is found from Oregon to British Columbia.

II. ANEMO′NE, Windflower, Anem′ony

Calyx of few or many petal-like sepals. Petals wanting. Akenes pointed or with long feathery tails. *Perennial herbs with stem leaves whorled, forming a kind of involucre some distance below the flower.*

III. THALIC′TRUM, Meadow-rue

Flowers diœcious in panicles. *Sepals 4–7, greenish. Petals none. Akenes in a head, terminated by long, naked styles.* Leaves twice or thrice palmately compound, leaflets 3-toothed or lobed, on short petioles. Generally tall, perennial herbs, often with a strong disagreeable odor. The species are difficult to determine.

IV. RANUN′CULUS, Buttercups

Sepals 5. *Petals 3–15, each with a little nectar-secreting scale or gland at the inside of the base.* Akenes in a head, numerous, usually flattish. Stem leaves alternate. Flowers generally yellow. (There are some that grow in the water with thread-like divisions to the leaves and small white flowers.)

a. **R. Califor′nicus Benth.** Stems branching from a cluster of thickened fibrous roots, erect, hairy. Root leaves of 3 leaflets with 3–7 linear divisions, or 3-lobed, with the lobes toothed. Sepals turned back. *Petals 10–15, glossy, yellow,* nearly ½ in. long. Akenes very flat, in a round head beaked with the stout, recurved styles. This is variable in size, leaves, and amount of pubescence. Throughout California.

b. **R. murica′tus L.** Stems stout, smooth, hollow. Flowers small. Akenes large with stout beaks, and *the sides covered with coarse prickles.* This grows in wet places and has been introduced.

c. **R. glaber′rimus Hook.** Perennial, with fleshy fibrous roots. Stems 3–6 in. high. *Root-leaves spatulate or wedge-shaped, entire or with 2–4 blunt teeth or lobes : stem leaves 3-cleft, with narrow divisions or* *entire.* Petals obovate, nearly ½ in. long. Akenes in a globose head, generally smooth, each tipped with a short beak. In the Sierra Nevada Mountains and northward to British Columbia. It blooms in the spring.

d. **R. tenel'lus Nutt.** Perennial, a foot or two high. Stems erect, hairy, or smooth. Leaves deeply lobed, 3–5 cleft, with the divisions more or less wedge-shaped, the margin with a few sharp teeth. Petals 5, small, yellow. *Akenes in a globose head, each tipped with a coiled style.* Receptacle smooth. This is widely distributed and variable. It blooms in the spring.

e. **R. occidenta'lis Nutt.** Perennial, a foot or two high. Stems widely branching, covered with widely spreading hairs. Leaves deeply cleft into 3–5 wedge-shaped divisions, these again cut; sometimes the leaves are compound with 3 leaflets on petioles. Upper leaves simpler and smaller. Petals 5, twice as long as the reflexed sepals. *Akenes tipped with flattened, hooked beaks on a smooth receptacle.* This is variable and widely distributed. It blooms in the spring.

f. **R. alismaefo'lius Geyer.** Perennial from thick fibrous roots. Stems in bunches, short and erect, about 6 in. high. *Leaves lance-shaped, tapering to margined petioles that widen at base;* upper leaves thickish, 2–4 in. long, nearly sessile. Corolla showy, yellow, nearly 1 in. across, with broad obovate petals. *Akenes in a globose head, smooth with a short beak.* This grows in marshy places in the Sierra Nevada Mountains and northward. It blooms in the spring.

V AQUILE'GIA, Columbine (ALSO MISTAKENLY CALLED Honeysuckle)

Sepals 5, petal-like, all similar. *Petals 5, each consisting of a tubular or expanded border terminating in a long hollow spur projecting below the sepals.* Pistils 5, forming many-seeded follicles. Perennial herbs with leaves twice or thrice palmately compound. Flowers usually nodding at the ends of the branchlets.

a. **A. trunca'ta Fisch & Meyer.** RED COLUMBINE. Flowers red, tinged with yellow. Sepals spreading. *Petals with scarcely any border, and thick, blunt spurs.* Throughout California growing in shady, moist places.

b. **A. formo'sa Fisch.** This resembles the preceding, except that the *border of the petals is prolonged, especially on the outer side.* This is found in Oregon.

VI. DELPHIN′IUM, Larkspur

Sepals 5, petal-like, the upper one prolonged backwards at the base into a spur. Petals 4, two running into the calyx spur, the others partly covering the pistils and stamens. Flowers in racemes. Fruit of 1–5 many-seeded follicles. Some of the species are poisonous to cattle. The blue Larkspurs are the most common, but they are difficult to distinguish.

a. **D. nudicau′le Torr. & Gray.** *Flowers scarlet, few, on long pedicels.* Sepals close together, spur long. Stems almost leafless, except at base, slender and delicate. This grows on moist, shady banks in the Coast Mountains.

b. **D. cardina′le Hook.** *Flowers bright scarlet with yellow centers, in a rather dense raceme.* Stems tall and stout. This grows in the mountains of southern California.

c. **D. Califor′nicum Torr. & Gray.** *Flowers in dense racemes, bluish gray, woolly on the outside,* spur horizontal, equaling the sepals. Stems 2–8 ft. high. Lower leaves 4–7 in. in diameter, deeply cleft, with wedge-shaped divisions. This generally grows on dry hills amid the brush along the coast.

VII. ACONI′TUM, Aconite, Monkshood

Sepals 5, petal-like, the upper one like a hood or helmet. The two upper petals have long claws and spur-like blades concealed within the hood; the 3 lower are much smaller or wanting. Fruit of 3–5 many-seeded follicles.

A. Columbia′num Nutt. Stems simple, leafy, 2–5 ft. high. Flowers in a loose raceme. Leaves palmately 3–5 cleft, with wedge-shaped, toothed, or cleft divisions. This is found at higher elevations in the Sierra Nevada Mountains in moist, shady places. In the northern part of the state it is found at much lower altitudes.

VIII. ACTÆ′A, Baneberry

Perennial from short, branched rootstocks, about a foot or two in height. Leaves 1 or 2, with broad triangular outline, 3–5 times compound; the leaflets ovate, irregularly cut and with the teeth on the margins unequal. *Flowers white, small, in a corymb lengthening to a raceme and terminating the stem,* blooming in spring. *Fruit consisting of red or white berries on spreading pedicels.*

A. spica′ta L. var. argu′ta Torr. Berries generally bright red, oblong or roundish, not quite so large as green peas, falling off soon when ripe. This grows in shady woods and the fruit ripens in late summer. It is considered poisonous. Widely distributed, on the coast and in the mountains.

IX. PÆO′NIA, Pæony

Stems several, from fleshy roots, erect at first, bending over in fruit. Leaves thrice-compound, leaflets cut into several segments. Flowers solitary at the ends of the stems. *Sepals 5. Petals 5, concave, brownish red.* Stamens many on a disk. *Fruit of 2–5 leathery follicles containing several large seeds.*

a. **P. Califor′nica Nutt.** *Leaves of pedate outline,* scarcely glaucous. Southern California.

b. **P. Brow′nii Dougl.** *Leaves cordate-ovate in outline,* very glaucous. From the higher Sierra Nevada Mountains to Oregon.

BERBERIDA′CEÆ. Barberry Family

Herbs or shrubs with pinnately compound leaves; bracts, sepals, petals, and stamens opposite each other instead of alternating. Anthers opening by little valves hinged at the top. Pistil simple.

I. BER′BERIS, Barberry, Oregon Grape

Flowers yellow, in clustered racemes with bracts. Sepals 6, petal-like. Petals and stamens 6. *Leaves odd-pinnate, with stiff spiny-toothed leaflets.* Fruit, in our species, a dark blue berry. Wood yellow.

a. **B. re′pens Lindl.** Oregon Grape. *Less than a foot high,* from slender woody rootstocks. *Leaflets 3–7, not shining,* somewhat glaucous, racemes few, terminal. Northern California to Alaska.

b. **B. aquifo′lium Pursh.** *Often 5 or 6 ft. high; leaflets 7–9, bright green and glossy,* sinuate-dentate. Racemes terminal. Fruit nearly round. In the Sierra Nevada Mountains from Kern County northward.

c. **B. pinna'ta Lag.** From less than a foot to about 2 ft. high. Leaflets prominently spiny, *the lowest pair near the base of the petiole.* Racemes both axillary and terminal. Hills of the Coast Mountains.

d. **B. nervo'sa Pursh.** MAHONIA, WATER HOLLY. Stem simple, *bearing a crown of large leaves at summit, mixed with many dry, chaffy, persistent bracts.* Leaves 1–2 ft. long, *leaflets 11–17*, somewhat palmately nerved. Racemes long. In deep woods from Monterey northward.

II. ACH'LYS, Oregon Sweet Clover and Deer's-foot, Sweet-in-death

Flowers on a scape forming a spike, without sepals or petals. Stamens 9, in 3 sets, with slender filaments and short anthers. Pistil with a broad, sessile stigma and a simple ovary. Fruit dry and indehiscent, kidney-shaped, thick and rounded on the back, thin and concave on the other side, with a fleshy ridge down the center. *Leaves large, of 3 leaflets, having the odor of new-mown hay, or vanilla, when they become dry.*

A. triphyl'la DC. Leaves and flowering stems from a creeping rootstock. Leaves with stalks a foot or more long and with the leaflets broadly wedge-shaped, 3–5 in. long, palmately veined and coarsely and irregularly wavy-margined.

This is found in northern California and northward to British Columbia. It grows in shady woods and is much prized on account of the lasting and sweet perfume of the dried leaves. It blooms in spring.

LAURA'CEÆ. LAUREL FAMILY

Aromatic trees or shrubs. Perianth of 6 petal-like divisions. Stamens 9, in 3 rows, the inner with 3 glands at base alternating with tongue-shaped staminodia. Anthers opening as in *Berberidaceæ.* Ovary free, 1-celled, forming a fruit like an olive.

UMBELLULA'RIA, California Laurel or Bay

Flowers perfect in umbels which before opening are included in involucres that are soon deciduous.

U. Califor′nica Nutt. Spice Wood. A large, handsome tree (sometimes shrubby), with smooth bark. Leaves evergreen, glossy, lanceolate-oblong, on short petioles. Flowers yellow, soon falling. Fruit green at first, dark purple or yellow when ripe, about 1 in. long, solitary, or 2 or 3 in a cluster, on a stout peduncle. This grows near or not far from water. Oregon to San Diego. It blooms often in December or even in November.

PAPAVERA′CEÆ. Poppy Family

Herbs or shrubs. Parts of the flower all separate (except the sepals of *Eschscholtzia*, which are united), and distinct on a top-shaped receptacle. Sepals falling off as the petals expand in the bud. Petals twice as many as the sepals, generally 4. Stamens numerous and conspicuous. Fruit a capsule with parietal placentæ. (In *Platystemon* the seeds are imbedded in the walls of the capsule in rows, each row forming a linear necklace-like follicle.)

I. ESCHSCHOLT′ZIA, California Poppy

Annual or perennial herbs. Leaves bluish green, succulent, usually cut into fine divisions. *Sepals united into a pointed cap, often seen on the opening flower. Petals 4, orange or yellow.* Stamens numerous, with long anthers. Stigmas 2–6. Pods long and narrow, ribbed, usually dehiscent from the apex, the valves frequently remaining attached at the sides. Receptacle often surrounded with a rim.

E. Califor′nica Cham. Annual or perennial, with succulent leafy stems. Flowers with a funnel-form receptacle and a broad or narrow rim. Petals broad, yellow or orange, often the two colors in the same flower. This is the commonest species and is widely distributed.

II. DENDROME′CON, Tree Poppy

Shrubs with erect branches. Leaves alternate, lanceolate, entire, stiff. *Sepals 2, large. Petals 4, generally large, light yellow.* Stigmas 2. Pod similar to that of the preceding, except that the valves are generally dehiscent from the base.

D. rig′ida Benth. This shrub is generally found on gravelly or clayey hills, growing to a height of from 2 to 8 ft. It is conspicuous on account of its numerous large yellow flowers, which may be found at all seasons. The bark is whitish. It is widely distributed.

III. PLATYSTE′MON, Cream Cups

Low, branching herbs. Stem leaves opposite or whorled, entire. *Sepals 3–6, cream-color*, often with a yellowish spot near the base. Stamens numerous, with flat filaments. Stigmas linear, separate, *one to each of the necklace-like pods, which at first are somewhat united ; but when ripe they separate and break apart between the seeds.*

P. Califor′nicus Benth. Stems branching from the base, from 6 in. to 1 ft. high. Leaves light green, hairy, broad-linear. Flowers not quite 1 in. in diameter. Pods from 6–25, forming an oblong cluster. This is common in early spring throughout California.

IV. PLATYSTIG′MA, Cream Cups

Stamens few or many, with narrow filaments. *Pod with 3 angles, splitting into 3 parts when ripe.*

a. **P. linea′re Benth.** This resembles *Platystemon*, but can be distinguished by the 3 stigmas and the 3-angled pods.

b. **P. Califor′nicum Benth. & Hook.** Stems long and slender, with branches 2-forked, smooth. *Flowers small, white.* Stamens about 12 in 2 circles. *Pod about 1 in. long, narrowly linear.* This is less common, and generally grows in the shade. Santa Barbara County to Oregon.

V. ARGEMO′NE, Prickly Poppy, Mexican Poppy, Thistle Poppy, Chicalote

Herbs with stout pale-green stems, and foliage more or less covered with spines or prickles. *Sap yellow. Leaves thistle-like.* Flowers large, white. *Sepals 3, each with a spine-like beak, forming a 3-horned bud.* Petals 4–6. Stamens numerous, on slender filaments. Pods 1-celled, opening at the top into 3–6 parts, the *ribs remaining fastened to the united stigmas.*

A. platy′ceras Link. & Otto. Stems smooth under the dense white prickles. Flowers 3–4 in. broad. Ovary densely covered with erect prickles. Central and southern California.

VI. ROMNE′YA, Matilija (Matil′iha) Poppy

Smooth, stout, perennial herbs, several feet high, with colorless sap. Leaves alternate, pinnately cut or divided, not spiny. *Sepals 3, each with a broad wing on the back. Petals 6, large, white.* Stamens many, with filaments diminishing towards the base. *Ovary covered with bristles. Pod 7–11-celled, the sides separating from the placenta.*

a. **R. Coul′teri Harv.** This beautiful plant is native in the southern part of the state. It is now widely cultivated. The flowers are sometimes 6 in. in diameter. *The buds are smooth.* This grows in southern California and is extensively cultivated.

b. **R. trichoca′lyx Eastwood.** This is similar to the above, but the *buds are hairy* and the *stems are not so robust.* The dissected leaves are close under the flowers. This is the true Matilija poppy, since it is the species found in the cañon of that name.

VII. MECONOP′SIS, Poppy

Annual herbs with yellow sap. Leaves variously cut into linear divisions. Sepals 2. Petals red or orange. Stamens numerous. *Stigma 4–8-lobed, on a distinct, stout style.* Pod 1-celled, with the valves separating as in *Romneya.*

M. heterophyl′la Benth. Flaming Poppy. Smooth and slender herbs with succulent stems and pale-green leaves. Flowers on long slender peduncles, exceedingly variable, from less than 1 in. to 2 in. in diameter, with pale-red petals becoming darker and more glowing at the center. Throughout California.

FUMARIA′CEÆ. Bleeding Heart Family

Perennial herbs. Leaves compound, cut into many narrow divisions. Flowers of peculiar shape. Sepals 2, petals 4, stamens 6 in 2 sets, with the filaments of each set somewhat united, the middle anthers 2-celled, the others 1-celled. Pod 1-celled, with the valves separating from the placenta.

I. DICEN'TRA, Bleeding Heart

Sepals 2, like scales. Corolla heart-shaped, the 2 outer petals swollen at the base, and with spreading tips; the 2 inner narrow, spoon-shaped, with a crest or keel on the back, united at the tips and covering the anthers and stigma. Style slender. Stigma 2-lobed, each lobe 2-crested, and so appearing 4-lobed.

a. **D. formo'sa DC.** Bleeding Heart. Leaves and flowering stems springing from creeping rootstocks, succulent and pale green, 1 or 2 ft. high. *Flowers rose-color, in compound racemes.* This grows in rich soil in the shade. From the Sierra Nevada Mountains to British Columbia.

b. **D. chrysan'tha Hook. & Arn.** Golden Eardrops. *Flowers golden yellow, in compound racemes.* Stems leafy, stout, 2–4 ft. high. Leaves twice pinnately compounded, often more than 1 ft. long. Sepals soon falling. Flowers more than ½ in. long. This showy plant grows in sunny places, usually on dry hills, throughout California. It is not common.

CRUCIF'ERÆ. Mustard Family

Herbs with pungent, watery juice. Leaves alternate without stipules. Flowers in racemes, spikes, or corymbs. Sepals usually 4, often falling early. Petals 4, with the blades in the form of a cross. Stamens 6, the 2 outer ones shorter than the 2 inner. Fruit a pod divided into 2 parts (except in the first 2 genera) by a transparent partition which stretches from one placenta to the other. The flowers of this family are so alike that genera and species cannot be determined without examining tolerably mature fruit.

**Pod not elongated, flowers usually very small.*

I. THYSANOCAR'PUS, Lace Pod

Flowers inconspicuous, white. *Fruit roundish, indehiscent, 1-seeded, surrounded by a prominent wing, which is crenate, filled with small, regular holes like embroidery, or with lines* *radiating from the seed to the margin.* Erect, branching, annual herbs, with leaves sessile and generally auriculate-clasping.

a. **T. cur′vipes Hook.** This is the commonest species. It has the fruit with crenate margin, often perforated. Widely distributed.
b. **T. ra′dians Benth.** This has much larger fruit than the preceding, with lines radiating from the center to the outside of the wing. This is found from California to Oregon.

II. ATHY′SANUS

Flowers very small. *Fruit roundish, not winged, generally covered with hooked prickles, indehiscent and 1-seeded.* Low, spreading, slender, delicate, hairy herbs, fruiting in spring.

A. pusil′lus Greene. This is the only species. It is widely distributed.

III. LEPID′IUM, Peppergrass

Flowers small, white or greenish, with petals often wanting. *Fruit roundish, usually notched at the apex, 2-celled, flattened contrary to the partition.*

a. **L. nit′idum Nutt.** Low annuals. *Pods shining, reddish, very numerous.* Leaves compound, with narrow, linear leaflets. This is one of the earliest plants of spring. Widely distributed.
b. **L. bipinnatif′idum Desv.** Low, almost prostrate herbs, with the lowest leaves twice divided, and divisions usually roundish. Petals wanting. *Pods round, on stout spreading pedicels.* Introduced. Common on roads and streets.
c. **L. apet′alum Willd.** Stems slender, a foot or so high, branching. Lower leaves toothed or more deeply divided, acute at apex. Flowers without petals, on erect pedicels that spread widely in fruit. *Pods smooth, round, notched at apex.* This is a weed which has been introduced and is now widely distributed.

IV. SENEBIE′RA, Wart Cress

Flowers greenish. *Pod of 2 globose, equal parts united, forming a twin pod.* Leaves pinnately parted. Low, spreading, introduced plants with a disagreeable odor.

S. pinnatif′ida DC. This is found along the coast, growing near flumes, drains, roads, etc.

V. CAPSEL′LA, Shepherd's Purse

Flowers small, white. *Pods elliptical or obcordate, 2-celled, flattened contrary to the partition.* Erect branching herbs with the leaves clustered at the base.

C. Bursa-pasto′ris Medic. SHEPHERD'S PURSE. This is the common dooryard weed, with obcordate pods in loose raceme.

** *Pod elongated. Flowers generally conspicuous.*

VI. RAPH′ANUS, Radish

Pod beaked, compressed between the seeds. Flowers large, orange, white or rose-purple, veined. These are coarse, hairy, erect, branching herbs with fleshy roots. Leaves cut into several divisions, the upper one much the largest.

R. sati′vus L. This is the common radish which grows wild throughout the settled parts of California. The petals are purplish, and the fruit is not strongly compressed between the seeds.

VII. BRAS′SICA, Mustard

Pod slender, terete, 2-celled, with a flattened beak. Flowers yellow. All probably introduced weeds.

a. **B. campes′tris L.** WHITE MUSTARD. Flowers in a loose raceme. *Leaves bluish green, smooth, clasping.* Pods large, spreading. This is very common and is in bloom earlier than the other species.

b. **B. ni′gra Koch.** BLACK MUSTARD. Flowers in close racemes at the ends of long stems, fragrant. Petals twice as long as the sepals. *Pods rather small, erect as if clinging to the stem. Stems often very tall.* This is common throughout California.

VIII. ERYS′IMUM, Wallflower

Pods spreading or erect, 1–5 in. long, 2–4-sided, with thick walls. Flowers fragrant, yellow or orange, at first in a corymb, which lengthens to a raceme. Petals with blade $\frac{1}{2}$ in. long. Erect rough herbs, with leaves linear or lanceolate.

a. **E. as′perum, DC.** Stems generally simple, often tall. Flowers generally orange. *Pods 4-sided.* Widely distributed and variable, especially in the color of the flowers.

b. **E. grandiflo′rum Nutt.** Stems 1 or 2 ft. high, simple or branched from the base. Flowers in a corymb, yellow, becoming paler after pollination. *Pod 2-sided, flattened contrary to the partition.* From Oregon to Los Angeles, not far from the coast. This includes many forms.

IX. NASTUR′TIUM, Cress

Pods short, oblong or linear, with thin walls. Flowers small, yellow or white. Leaves usually pinnately divided.

N. officina′le L. Water Cress. This is common in all the streams.

X. BARBARE′A, Wintercress, Yellow Rocket

Pods somewhat 4-sided, flattened parallel to the partition, about 1 in. long, spreading upwards. Seeds in 1 row in each cell. Flowers yellow, with petals twice as long as the sepals, in a short, dense raceme. *Lower leaves compound, with the terminal leaflet rounded and larger than the others;* upper leaves generally simple.

B. vulga′ris R. Br. This is the only species. It grows in damp places and blooms in early spring. Widely distributed.

XI. PLATYSPER′MUM

Flowers very small, solitary, on naked scapes. Sepals broad, erect, equaling the white, linear-spatulate petals. *Pods almost orbicular, with broadly winged, veiny seeds in 2 rows.* Leaves lyrate, with few lobes or almost none.

P. scapig′erum Hook. Scapes 1–6 in. in height in fruit. Flowers about $\frac{1}{12}$ in. long. Pod $\frac{1}{4}$–$\frac{1}{2}$ in. long, containing 8–12 seeds. This is found on the eastern slope of the Sierra Nevada Mountains from California north to Washington. It blooms in early spring.

XII. DENTA′RIA, Toothwort, Pepper-root

Pods linear, flattened parallel with the partition, walls firm without nerves, stigma short. *Seeds in 1 row, wingless. Flowers large, pale rose-color or milky white.*

D. Califor′nica Nutt. Milkmaids. Rootstocks bearing tubers which easily break off. Root leaves simple and round-kidney-shaped or with 3 leaflets (usually not found on the blooming plant); stem leaves with from 3 to 5 pinnate leaflets on petioles. This is one of the loveliest and most common of the early spring flowers, usually found in damp places. Widely distributed in the Coast Mountains.

XIII. CARDA′MINE

Pods linear, flat, with the seeds in 1 row, wingless. This is similar to *Dentaria, but has smaller flowers, narrower pods, and smaller seeds.* The chief differences lie in the cotyledons, which in *Cardamine* are flattened, while in *Dentaria* they are thick, unequal, and oblique.

C. oligosper′ma Nutt. Annual, slender, hairy or smooth. Leaves pinnately divided, with small 3–5 lobed or toothed divisions which are on small petioles. Flowers small, $\frac{1}{4}$ in. long, white, in few-flowered racemes, on short peduncles. Pods erect, on short stipes and containing 8–20 seeds. This grows in shady, damp places; it blooms in the spring and is widely distributed along the Pacific Coast.

XIV. AR′ABIS, Rock-cress

This is similar to the preceding, except that *the walls of the pods are nerved, roots woody, and seeds usually with a border or wing.* Flowers white or rose-color, often conspicuous.

a. **A. perfolia′ta Lam.** Tower Mustard. Biennial herbs with stems bluish green, erect, 1 or 2 ft. high. Stem leaves *arrow-shaped and clasping.* Root leaves hairy, soon withering. Flowers small, white. *Pods numerous, slender, erect, parallel, and close to the stem.* Seeds generally narrowly winged. Widely distributed.

b. **A. blepharophyl′la Hook. & Arn.** Stems low, from a tuft of broadly spatulate, dark-green leaves, with long hairs on the margins. *Flowers large, fragrant, reddish purple.* Pods beaked, flat, loosely spreading. Seeds with a narrow wing, in 1 row. This is perennial and is found on rocky hills near the coast from San Francisco to Monterey.

c. **A. hirsu'ta Scop.** Biennial, hirsute especially at base, with spreading hairs which are simple or forked. Stems erect, simple or branched, 1–3 ft. high. Leaves at base oblanceolate, coarsely toothed or entire, 1–2 in. long, on winged petioles; *stem leaves cordate or auricled at base.* Flowers very small. Petals greenish white. Pods erect on slender pedicels, very narrow, 1–2 in. long; stigmas nearly sessile. Seeds with a narrow margin. This blooms in spring and is found from northern California to Alaska.

d. **A. Holboel'lii Hornem.** Biennial, clothed with fine stellate pubescence. Stems 1–several, simple or branched. Leaves at base oblanceolate, narrow, entire. Stem leaves arrow-shaped. Flowers becoming deflexed and generally growing on one side of the peduncle. Petals white or pink, $\frac{1}{4}$ in. long. *Pods flat, reflexed; stigmas sessile. Seeds in 1 row, orbicular, winged.* This blooms in the spring and is very widely distributed.

XV. STREPTAN'THUS, Jewel-flowers

Pods linear-oblong, flattened parallel with the partition, on a broad receptacle. Seeds flat, with a margin or wing. *Sepals usually bright purple or white, uniting somewhat to form a closed calyx. Petals narrow, with spreading blades.* Anthers long, arrow-shaped; filaments of the larger stamens often united into 2 pairs. The species are numerous and difficult to distinguish.

XVI. STANFOR'DIA (NAMED FOR HON. LELAND STANFORD).

Pods linear oblong, flattened contrary to the partition. Stigma 2-lobed, on well-developed pods. Otherwise similar to *Streptanthus.*

S. Califor'nica Watson. This is the only species. It is found in the southern San Joaquin Valley, where it is very abundant in some parts in early spring.

XVII. CAULAN'THUS, Wild Cabbage

Pods terete, or somewhat flattened, parallel with the partition. Flowers similar to the two preceding, except that the *petals have broad claws, and the blades are scarcely evident.* Tall herbs, often with inflated stems. The species are mostly local and not readily distinguished.

XVIII. THELYPO′DIUM

Pods slender, terete, or 4-sided, and often twisted, on a slender stipe. Flowers white or purplish. Stamens long, conspicuous, with very narrow, arrow-shaped anthers. *Sepals at first united to form a tube, afterwards spreading.*

T. lasiophyl′lum Greene. Erect, smooth below, hairy above. Leaves toothed or pinnately lobed or divided, with spreading segments. Flowers small, yellowish white. Pods slender, narrowed to the apex, deflexed on curved pedicels. (One variety has erect pods.) This is common, especially in cultivated ground.

XIX. STANLE′YA

Pods long and terete on a raised receptacle, with 1 row of seeds in each cell. Flowers bright yellow or cream-color, with long, narrow, spatulate petals with slender claws; anthers linear, spirally coiled, on long filaments.

S. pinnatif′ida Nutt. Golden Prince's Plume. This is the only known Californian species. The long conspicuous stamens and the long, loosely and thickly flowered plume-like clusters of golden-yellow flowers suggested the common name to Helen Hunt Jackson. Southern California, common in arid districts.

CAPPARIDA′CEÆ. Caper Family

Herbs or shrubs with alternate palmately compound leaves of 3 leaflets. Flowers as in *Cruciferæ,* except that the stamens are all equal. Pods on long stipes, 1-celled, with 2 parietal placentæ. Many flowers have the pistil rudimentary and never produce fruit.

ISO′MERIS, Bladderpod

Shrubby, with hard, yellow wood. Leaflets as long as the petiole. Flowers in racemes with bracts, generally simple. Corolla yellow, ½ in. in diameter. Pods inflated, pear-shaped, drooping, on long slender stipes.

I. arbo′rea Nutt. This is the only species. It is found in southern California, where it is quite common.

CRASSULA′CEÆ. Stonecrop Family

Thick, fleshy herbs. Sepals, petals, stamens, and pistils all of the same number, or stamens twice that number. The pistils become follicles in fruit.

I. SE′DUM, Stonecrop

Sepals 4 or 5, united at base. Petals distinct, spreading, star-like. Flowers in cymes, generally on one side of the flowering axis, deep purple, yellow, or white. No one species is widely distributed in California.

a. **S. spathulifo′lium Hook.** Perennial. Stems spreading by runners and rooting at the rose-like bunches of fleshy leaves. Leaves glaucous, obovate or spatulate, flat, $\frac{1}{2}$–3 in. long. Flowering stems erect, capped by a *cyme of yellow flowers, which are almost sessile, and disposed to be on one side of the peduncles.* Petals twice as long as the ovate sepals, a little longer than the stamens and style. This blooms in summer. It grows on rocks that are clothed with moss and are wet during the rainy season, but later become dry. It is common from middle California to Washington.

b. **S. Orega′num Nutt.** This is similar to the above but is not glaucous. Flowers larger. *Petals pale rose-color*, narrowly lanceolate, with pointed apex, nearly twice as long as the stamens. This is found from northern California to Washington.

c. **S. pu′milum Benth.** *Annual*, slender, with stems simple or branched, 1–6 in. high. Leaves $\frac{1}{6}$ in. long, ovate-oblong. Flowers yellow, sessile, in cymes. Calyx lobes very small, triangular, acute. Petals linear, acute, exceeding the calyx, stamens, and styles. *Follicles 1-seeded, with the seed filling the cavity.* This is widely distributed in the Coast and Sierra Nevada Mountains. It blooms in summer and generally grows on northward slopes or on shady rocks.

II. COTYLE′DON (ECHEVERIA)

Calyx 5-parted. Petals united into a cylindrical corolla. Stamens 10, on the tube of the corolla. Leaves entire, thick, and fleshy, forming large clusters at the base of the flowering stem. Flowers red or yellow, in long racemes or cymes, coiled somewhat at the tip. The species are difficult to distinguish and mostly local.

SAXIFRAGA′CEÆ. Saxifrage Family

Herbs or shrubs. Leaves opposite or alternate without stipules. Calyx either free from or partially united to the ovary. Petals and stamens inserted on the calyx. Stamens not more than twice the number of calyx lobes. Carpels 2–5, partially or completely united into a compound ovary. Styles distinct. Seeds with endosperm. In the currants and gooseberries the fruit forms a berry.

I. SAXIF′RAGA, Saxifrage

Herbs with simple or palmately lobed leaves and cymose or panicled flowers. (Flowers rarely solitary.) Calyx 5-lobed, either free from the ovary or with the lower part of the tube coherent. Petals 5, entire, inserted on the calyx tube. Stamens 10. *Capsule consisting of 2 carpels united at the base, the styles soon diverging and becoming beaks on the akenes. Placenta axillary.* Leaves often in radical clusters and flowers on a scape.

S. Califor′nica Greene. Leaves few, rather thick, somewhat clothed with glandular hairs, oval to elliptical, on broad petioles; margin crenate or dentate. Scape 6–18 in. high; flowers in a loose panicle. Calyx nearly free from the ovary, with reflexed sepals. Petals oblong, white, thrice as long as the sepals. Stamens with filaments inserted under the edge of a disk which equals the summit of the ovary. Blooming in early spring and found on cool slopes throughout California.

II. BOYKIN′IA

Perennial herbs with creeping rootstocks, leafy stems, and paniculate corymbs or cymes of small white flowers. Leaves alternate, round-kidney-shaped, palmately lobed or toothed, the teeth glandular at tip; petioles with stipule-like dilations at base. *Calyx 5-lobed, with globular tube, adherent to the ovary.* Petals 5, entire. Stamens 5, with short filaments. *Pod splitting down the beaks, 2-celled.*

B. occidenta′lis T. & G. Diffusely branched, with slender stems 1 or 2 ft. high. Leaves somewhat scattered, thin, 5–7-lobed, 1–3 in.

broad; petioles with brown bristles at base. Calyx with urn-shaped tube and triangular lobes. Petals recurved in age, wedge-shaped. This grows along rocky streams from middle California to British Columbia. It blooms in the summer.

III. TELLI′MA

Perennial herbs from rootstocks or tubers. Leaves mostly radical, round-cordate, toothed or palmately divided, with petioles dilated at base. Flowers in a simple raceme. *Calyx bell-shaped or urn-shaped, with the base attached to the lower half of the ovary.* Petals 5, fringed, lobed, or entire, white or rose-color. Stamens 10. Styles 2 or 3, short, with round stigmas. *Capsule slightly beaked by the persistent styles, and opening between the beaks.*

a. **T. grandiflo′ra Dougl.** Fringed Cups. Stems rather stout, 1–2 ft. high, from a woody rootstock. Radical leaves 2–4 in. broad. *Flowers with inflated calyx and petals rose-color, fringed.* This grows in moist, shady places. From Santa Cruz to Alaska.

b. **T. af′finis Bolander.** Stems slender, about a foot high, from a tuber-bearing rootstock. Radical leaves round-kidney-shaped, slightly lobed; stem leaves 3-lobed to the middle, with coarsely toothed lobes. *Calyx narrowed at base, with its tube adhering to the ovary.* Petals white, the lower 3-toothed, the upper narrower, shorter, and entire. In shady places almost throughout the state.

c. **T. heterophyl′la Hook. & Arn.** Similar to the preceding in stem and general appearance. Radical leaves with 5 shallow, rounded lobes, stem leaves more deeply 3-lobed or parted. *Calyx bell-shaped, the base adhering to the ovary.* Petals 3-lobed. Common in the Coast Mountains, in shady places.

d. **T. parviflo′ra Hook.** Stems slender, about a foot in height, clothed with rough pubescence. Leaves 3–5-parted, with the divisions wedge-shaped and cleft into narrow lobes. *Calyx wedge-shaped, half adhering to the ovary.* Petals 3-cleft, with the divisions linear or oblong. Besides the bulblets on the slender rootstocks, there are generally some on the few-flowered raceme. Blooming in spring and found from northern California to British Columbia.

e. **T. tenel′la Watson.** Stems slender, 2–9 in. high, rough with glandular pubescence. Leaves similar to the preceding but smaller. *Calyx bell-shaped, with the base roundish or acute, adherent only at base.* Petals 3–7-parted into linear divisions. This also has bulblets on the rootstock and racemes. Blooming in spring and found from northern California to Washington.

IV. TOLMIE′A

Perennial herbs with slender, creeping rootstocks and sometimes runners. Leaves mostly from the root. Flowers small, in a loose raceme. *Calyx funnel-form, free from the ovary, thin and swollen at base, with unequal lobes. Petals 4–5, thread-like, recurved, persistent.* Stamens 3, inserted in the throat of the calyx; filaments short, and anthers with the 2 cells running into one. Pod oblong, with the base tapering to a short stem, *splitting between the diverging equal beaks.*

T. Menzie′sii T. & G. Stems 1–2 ft. high, hairy with stiff hairs. Leaves round, heart-shaped, crenately toothed; petioles slender; stem leaves few. Raceme nearly a foot long, flowers greenish or purplish, nearly ½ in. long, including the capsule. Blooming in spring and summer and found from northern California to Washington.

V. HEU′CHERA, Alum Root

Perennial herbs from stout rootstocks. Leaves all radical, cordate, lobed and toothed, the veins often colored red. Flowers small in a panicle. *Calyx generally campanulate, with base attached to the lower half of the ovary.* Petals 5, entire, small, soon falling. *Ovary and capsule 1-celled, with 2 parietal placentæ and 2 styles which become beaks on the capsule.*

a. **H. micran′tha Dougl.** This is the commonest species. It is conspicuous on moist, shady banks because of its beautiful red-veined leaves. *The flowers are quite small, and the panicle is loosely and numerously flowered.* Common in shady places in the Coast and the Sierra Nevada Mountains.

b. **H. cylin′drica Dougl.** Leaves all from the root, round-kidney-shaped, lobed or crenately toothed, 1–2 in. broad. *Flowers greenish, in spikes,* terminating leafless scapes, 1–2 ft. high. Calyx lobes erect, oblong, and elongated. Petals very small or wanting. Stamens and style short. Blooming in spring. Washington and Oregon.

VI. TIAREL′LA

Perennial herbs with simple or compound leaves with stipules. Flowers small, white, in a panicle or raceme. Calyx 5-parted, with valvate lobes. Petals 5, entire, with claws. Stamens 10, inserted with the petals at the base of the calyx. Anthers 2-celled. *Ovary 1-celled, of 2 valves, which soon separate and become unequal, one elongating, the other remaining short.* Seeds few at the base of the placentæ. Blooming in summer and found from northern California to British Columbia.

T. unifolia'ta Hook. Stems slender, ½–1½ ft. high. Leaves ovate-cordate, 3-5-lobed; those from the root on long petioles; stem leaves few, on short petioles. Panicle narrow. This is found in shady woods from northern California to British Columbia. It blooms in the summer.

VII. RI'BES, Currant, Gooseberry

Shrubs with alternate, palmately veined and lobed leaves. Flowers solitary or in racemes at the ends of leafy branchlets, sometimes blooming before the leaves. Calyx with tube attached to the globose ovary and extending beyond it, the border 4 or 5 cleft, usually colored. Petals erect, smaller than the calyx lobes. Stamens alternating with the petals. *Fruit a berry, smooth or prickly, containing many seeds, and generally surmounted by the withered remains of the flower.*

a. **R. specio'sum Pursh.** FUCHSIA-FLOWERED GOOSEBERRY. Tall, with prickly branches armed with 3 large thorns under each cluster of leaves. Leaves thick, small, smooth, nearly evergreen. Flowers 2–5, on a glandular-bristly peduncle, *bright red, with the parts four, almost 1 in. long, drooping. Stamens protruding from the corolla.* Berry dry, densely glandular-bristly. Common in southern California.

b. **R. divarica'tum Dougl.** GOOSEBERRY. Stems destitute of prickles except on young shoots, with 1–3 thorns under each cluster of leaves. Calyx greenish white or purple. Petals white, fan-shaped, much shorter than the filaments and 2-cleft style. *Berry dark red, smooth.* Widely distributed.

c. **R. sanguin'eum Pursh.** FLOWERING CURRANT. *Stems without prickles or thorns, usually glandular.* Racemes numerous, many-flowered, drooping. Flowers rose-color. Berries black or covered with a bloom. This is one of the earliest-blooming plants, sometimes flowering in November. The flowers appear before or with the leaves, and the whole plant is very fragrant. Some botanists consider that several species are included in this. Widely distributed.

d. **R. bracteo'sum Dougl.** Tall shrub, without prickles or thorns, smooth. Leaves sprinkled with resinous dots, 3–9 in. broad, 5–7-cleft, with pointed lobes and doubly serrate margins ; petioles long. *Racemes many-flowered, becoming 1 ft. long, with persistent bracts which are thread-like above and become leaf-like below.* Flowers greenish white. Calyx saucer-shaped. Fruit a black berry, sprinkled with resinous dots. Blooming in spring and found from northern California to Alaska.

e. **R. ce'reum Dougl.** Shrub with many short, stout branches, which are glutinous and sprinkled with resinous dots. Leaves 1 in. broad, kidney-shaped, 5-lobed, crenately toothed. Racemes with 3–5 flowers on short peduncles. Calyx white, with a greenish or pinkish cylindrical tube $\frac{1}{2}$ in. long, the lobes recurved. Petals orbicular. *Fruit a scarlet berry with a sweet, resinous taste.* Blooming in the spring and found from northern California to Washington.

f. **R. lacus'tre Poir.** Low shrub with prickly stems and thorns under the leaf axils. Leaves 3–5-parted, their lobes deeply cut. Calyx saucer-shaped, petals small, stamens and style short. *Fruit a reddish berry more or less covered with prickles.* From northern California to Washington. The variety **molle** Gray is the form common in the mountains of California. This species has the fruit and the prickly stems of the gooseberry but the racemed flowers of the currant.

VIII. PHILADEL'PHUS, Mock Orange, Syringa

Shrubs with diffuse branches, several feet in height. Leaves opposite, entire or toothed, ovate or oblong, without stipules. Flowers showy, white, in paniculate cymes. *Calyx with tube adnate to the ovary almost to its top, with 4–5 divisions which are valvate in bud.* Petals 4 or 5, large, obovate, *convolute in bud.* Stamens many, with slender filaments. Styles 3–5, united at base or almost to the top. Pod 3–5-celled, splitting from the apex when ripe, each valve 2-parted. Seeds many, pendent on placentæ projecting from the axis.

a. **P. Lewis'ii Pursh.** Nearly smooth. Leaves ovate, 1–2 in. long, nearly entire. *Panicle on a naked peduncle. Styles distinct at apex only,* stigmas narrow. Blooming in spring and found in the Sierra Nevada Mountains from California to British Columbia.

b. **P. Gordonia'nus Lindl.** Almost smooth. Leaves ovate to oblong, 2–4 in. long, coarsely serrate with scattered teeth. Flowers in loose clusters with *the peduncles leafy at base. Styles distinct to the middle.* Blooming in spring, in the Coast Mountains, from northern California to Washington.

IX. WHIP'PLEA

Low shrubs, with trailing stems and branches. Leaves opposite, 3-ribbed, toothed. *Flowers in small cymes on slender, naked stems.* Calyx 5-cleft, with white divisions, the tube attached to the lower part of the ovary. Petals 5, very small. *Ovary 3–5-celled, with 1 seed in each cell. Styles as many as the cells.*

W. modes'ta Torr. This is always found in woods of the Coast Mountains, particularly in the redwoods.

CALYCANTHA'CEÆ. Sweet Shrub Family

Aromatic shrubs with opposite leaves and no stipules; sepals, petals, and stamens passing into each other, and all uniting below into a closed cup which is lined by a hollow receptacle bearing numerous simple pistils.

Calycan'thus occidenta'lis Hook. & Arn. Sweet Shrub. Sepals numerous, imbricated, their bases united in many ranks into a cup-shaped tube, the outer bract-like, the inner linear-oblong; petals similar. Flowers terminal, reddish purple, fragrant, with an odor like benzoin. This grows near streams and is more frequent in northern California.

ROSA'CEÆ. Rose Family

Herbs, shrubs, or trees with alternate stipulate leaves. Stamens numerous, inserted on the persistent calyx or on a calyx-like receptacle. Ovaries from one to several. Seeds few, without endosperm. This family contains some of our most valuable fruits, such as the apple, pear, quince, almond, peach, plum, apricot, cherry, raspberry, blackberry, and strawberry. There are three great subdivisions or suborders.

Suborder I. — AMYGDA'LEÆ

Trees or shrubs. Fruits with a fleshy exocarp enclosing a hard endocarp, called a drupe or stone fruit (*f.* Fig. 170; *e.* Fig. 180), as the plum, peach, almond, etc.

I. NUTTAL′LIA (OSMARO′NIA)

Shrubby, *diœcious.* Flowers white, in drooping racemes. *Carpels 5, usually only 1 or 2 ripening.* The stipules soon fall. The leaves when crushed have the odor of bitter almonds.

N. cerasifor′mis Torr. & Gray. Oso Berry. Stems erect, generally growing in clumps, the male plants being much more numerous than the female. Racemes shorter than the leaves, with conspicuous bracts. Calyx broadly funnel-shaped, with a 5-toothed border. Petals 5, spatulate. Stamens 15, 10 erect in a line on the calyx, 5 below deflexed. Carpels on the disk at the base of the calyx. Fruit black-purple, with bitter pulp, furrowed slightly on the inner side. This often blooms in January in the Coast Mountains, but is much later in the Sierra Nevada. Widely distributed.

II. PRU′NUS, Plum, Cherry

Trees or shrubs. Flowers perfect, white. *Pistil only 1, forming a stone fruit.*

a. **P. demis′sa Walp.** Chokecherry. Trees or shrubs with serrate leaves. *Flowers in many-flowered drooping racemes.* Fruit globose, red, or dark purple, astringent. Widely distributed.

b. **P. ilicifo′lia Walp.,** Islay. Tree or shrub *with glossy evergreen, spiny, holly-like leaves.* Racemes from ½ to 2 in. long. Fruit somewhat flattened, ½ in. thick, sweetish, the stone large and the pulp thin. From San Francisco to San Diego.

c. **P. emargina′ta Walp.** *Small tree* with slender, reddish twigs, which are generally smooth. Leaves obovate or oblanceolate, obtuse or acute, serrate with fine teeth, *with 2 glands near the summit of the petiole. Corymbs shorter than the leaves, with few, white flowers.* Fruit a dark red cherry, which is bitter and astringent.

d. **P. Califor′nica Greene.** *Shrub* with the branches from the root, smooth and shining. Leaves obovate to oblanceolate, obtuse, emarginate, or even acute, serrate with fine teeth and with *1 gland on the lower part of the blade. Flowers few in a short corymb.* Fruit a red cherry, which is very bitter. In the mountains throughout middle and northern California.

e. **P. subcorda′ta Benth.** Tree or shrub with thorny branches. Leaves ovate, 1 in. long, with the base wedge-shaped or heart-shaped, the margin finely and sharply serrate. *Flowers white, in few-flowered umbels.* Fruit a red plum, ¾ in. long, not palatable. This is common in the Coast Mountains of California. The variety **Kelloggii Lemmon** has yellow fruit, which is sweet and palatable. It is found in the northern Sierra Nevada Mountains.

SUBORDER II. — **RO′SEÆ**

Pistils few or many (sometimes only one) separate from each other and free from the persistent calyx; sometimes, as in the rose, enclosed and concealed in the hollow receptacle. Stipules united to the bottom of the petiole. Many are armed with spines or prickles, and some are valuable fruits, as the strawberry, raspberry, blackberry.

I. NEIL′LIA (PHYSOCAR′PUS), Ninebark, Bridal Wreath

Shrubs without thorns or prickles, the bark becoming shreddy. Leaves roundish, lobed and toothed, with large stipules. *Flowers in corymbs resembling umbels, on short leafy branchlets disposed along the stems.* Petals white. Calyx 5-lobed. Stamens numerous. *Pistils 1–5, becoming inflated, shining, 2-seeded pods.*

N. opulifo′lia Benth. & Hook. 3–10 ft. high, the slender stems often apparently climbing over the bushes. Pods becoming reddish when ripe. Widely distributed.

II. SPIRÆ′A, Hardhack

Similar to the above, except that the flowers are in *compound corymbs or panicles terminating the stems or branches, the pods are membranous and not inflated,* and the leaves generally without stipules. Pistils 5, becoming several-seeded follicles.

a. **S. densiflora Nutt.** A shrub with reddish bark, *leaves almost smooth.* Flowers rose-purple, in compound corymbs. In the Sierra Nevada Mountains.

b. **S. Douglas′ii Hook.** HARDHACK. A shrub with reddish brown bark, *leaves white on the lower surface,* flowers rose-purple, in panicles, stamens numerous, giving the cluster a woolly appearance. Northern California to British Columbia.

III. HOLODIS′CUS, Meadow-sweet

Generally taller and with small white flowers in spreading panicles. Stamens 20, inserted on a disk like a ring. *Pistils 5, becoming 1-seeded carpels which are dehiscent by one side or not at all.*

a. **S. ariæfo′lius.** Shrub with dark brown, smooth bark, leaves silky-whitish beneath, flowers white, turning brownish, in loosely flowered plumose panicles, somewhat drooping in flower, erect in fruit. Blooming in early summer and growing along the woods of the Coast Mountains.

b. **H. dis′color Maxim.** Shrub with short, rigid branches, clothed with gray-brown, shreddy bark. Leaves deep green and almost smooth above, clothed with white tomentum on the lower surface. Panicles erect on short, erect branches. This is found on the eastern slopes of the Sierra Nevada Mountains, and north to Oregon and Washington.

IV. CERCOCAR′PUS, Mountain Mahogany

Shrubs or small trees. Leaves simple, entire or toothed, evergreen. Flowers axillary, small. Calyx with a long tube and a saucer-shaped border. Petals absent. *Carpels included in the calyx tube, usually 1, tipped by a long, feathery style.*

a. **C. ledifo′lius Nutt.** *Leaves lanceolate with revolute margins*, thick and resinous, white-downy on the lower surface, smooth above. Flowers sessile, downy. Tail of fruit 2 or 3 in. long. Chiefly found on the eastern slope of the Sierra Nevada Mountains, north to Oregon and Washington. Spring.

b. **C. parvifo′lius Nutt.** Shrubby, though sometimes 15 or 20 ft. high. *Leaves obovate, wedge-shaped at base*, thinner than the preceding, with silky hairs above and white down beneath. Flowers on short, slender pedicels. Tail of fruit 3 or 4 in. long. Common, widely distributed, and variable. Spring.

V. PURSH′IA (KUN′ZIA), Buckbush

Low, diffusely branched shrubs. Leaves in bunches on the stem, wedge-shaped. Flowers small, at the ends of short branchlets. Calyx funnel-shaped. Petals 5, yellow, longer than the calyx lobes. Stamens many, in 1 row. *Carpels 1* *or 2, narrowed at each end, projecting from the calyx, but the style not becoming longer in fruit.*

P. tridenta'ta. Leaves 3-lobed at apex, covered with white down on the under surface. Calyx also downy. This is common in the lower mountains, especially on the eastern side of the Sierra Nevada Mountains. Late spring.

VI. ADENOS'TOMA, Chemisal, Greasewood

Evergreen shrub with linear, resinous leaves. Flowers small, white, in panicles. Calyx with a 10-ribbed tube and broad, membranous lobes. Petals 5, round. *Stamens generally from 10 to 15 in clusters between the petals. Fruit 1-seeded, included in the calyx tube.*

a. **A. fascicula'tum Hook. & Arn.** CHEMISAL, GREASEWOOD. Stems many, the slender, reddish branches covered with close clusters of *very small, heather-like leaves; stipules small, acute.* Flowers crowded, nearly sessile. This often exclusively covers acres, usually growing on dry hills.

b. **A. sparsifo'lium Torr.** YERBA DEL PASMO. Tree or shrub *with narrowly linear, scattered leaves, without stipules.* Flowers larger than the preceding, on distinct pedicels. This is found in southern California. It is very fragrant, and much used as a remedy for colds by the Indians.

VII. GE'UM, Avens.

Perennial herbs. Leaves chiefly radical, pinnately divided, with petioles sheathing the stem and stipules attached. Flowers about as large as a nickel, solitary or generally in corymbs. Calyx open-bell-shaped, valvate in bud, with bractlets between the lobes. Petals 5, purplish or yellow. *Carpels very numerous, on a dry receptacle, the style becoming long; in fruit either bent in the middle or feathery.*

a. **G. macrophyl'lum Willd.** Stems 1–3 ft. high, hairy. Leaves with the largest division at the tip. Corolla yellow, with broad lobes longer than the sepals. Receptacle of the fruit smooth. *Styles bent near the middle, the upper part falling, leaving the lower part hooked.* In the mountains. Summer.

b. **G. stric'tum Ait.** Similar to the preceding but less hairy. Receptacle of fruit downy instead of smooth. In the mountains.

c. **G. riva′le L.** Somewhat similar to the preceding in habit of growth. Calyx brownish purple. Petals purplish, broad, with a short claw. *Style bent in the middle, but the upper part feathery.* In the mountains. Summer.

d. **G. triflo′rum Pursh** (**G. cilia′tum**). About a foot high. Leaves all radical, except for a few bract-like leaves on the scapes, pinnate, with leaflets crowded and irregular in size. Flowers usually 3, on long peduncles, large, reddish purple. Calyx with bractlets longer than its lobes, equaling the petals. *Styles straight, long, and feathery.* Widely distributed. Summer.

VIII. CHAMÆBA′TIA, Mountain Misery, Tarweed

Low, evergreen, glandular-aromatic shrub. *Leaves tri-pinnately dissected with the ultimate segments minute;* stipules small, linear, entire. Flowers about as large as a dime, in terminal cymes. Calyx with top-shaped tube and 5-lobed border. Petals white, 5, obovate. Stamens many. *Pistil one becoming a large akene.*

C. foliolo′sa Benth. This is the only species. It covers the ground under the pines in the Sierra Nevada mountains. Its fern-like foliage, strong odor, and abundant viscidity cause it to be well known.

IX. POTENTIL′LA, Cinquefoil, Five-finger

Herbs (one species shrubby) with compound leaves, toothed leaflets, and stipules attached to the petiole. *Calyx saucer-shaped or bell-shaped, 5-cleft and with 5 smaller bractlets.* Petals 5, yellow (rarely white). *Akenes on the receptacle, which is dry and smooth or hairy.*

a. **P. Anseri′na L.** Silvery Cinquefoil. *Stems prostrate, with runners like a strawberry.* Leaves pinnately compound with from 7 to 21 leaflets (smaller ones interposed), sharply serrate and silvery white on the lower surface. Flowers yellow, nearly an inch in diameter, petals falling easily. Receptacle very woolly. This is common in wet places everywhere.

b. **P. glandulo′sa Lindl.** Erect, a foot or two high, covered with glandular hairs. Leaves pinnately compound with from 5 to 7 leaflets. *Flowers in cymes that become open and spreading in fruit.* Petals yellow or yellowish white. Stamens 25 in one row. This usually grows in rather shady places. Widely distributed.

c. **P. gra'cilis Dougl.** Stems 1–3 ft. high, clothed with woolly hairs. Leaves palmately or pinnately compound, with *7 or more deeply lobed or coarsely serrate leaflets which are white-tomentose on the lower surface.* Flowers yellow, in loose, ample cymes. Akenes 40 or more, smooth. This blooms in the spring and is widely distributed in the mountains. There are many species very difficult to distinguish.

X. FRAGA'RIA, Strawberry

Calyx 5-lobed and with 5 alternate bractlets. Petals 5, white, spreading. Stamens many in one row. *Carpels numerous, on a fleshy receptacle which becomes red when ripe, and is called the fruit.* Leaves palmately compound with 3 toothed leaflets. Low plants, sending out running stems that root and form new plants.

a. **F. Chilen'sis Ehr.** Coast Strawberry. *Leaves thick, deep green, glossy above, hairy beneath.* Flowers white, an inch in diameter. The fruit is delicious, and the akenes are in depressions on the fleshy receptacle. This usually grows on sandy hills near the sea from San Francisco to Alaska.

b. **F. Califor'nica Cham. & Schl.** Wood Strawberry. *Leaves thin, light green, slightly hairy on both sides.* Flowers half an inch in diameter.. Fruit small, with the akenes on the surface of the receptacle, not in depressions. This is generally found on wooded slopes of the Coast Mountains.

XI. RU'BUS, Raspberry

Calyx *persistent, 5-lobed, without bractlets.* Petals 5, generally conspicuous. Stamens numerous, *carpels numerous on a conical receptacle, each becoming a tiny, round stone fruit.* Leaves simple or compound, with stipules adnate to the petiole.

a. **R. Nutka'nus Moc.** Thimble-berry, Scotch Caps. Erect shrub with large, 5-lobed leaves, which have gland-tipped hairs on the veins beneath and on the leafstalks. *Flowers white or pale rose-color, an inch or more in diameter. Fruit red, shaped like an inverted saucer, sweet and rather dry.* From middle California to Alaska.

b. **R. specta'bilis Pursh.** Salmon-berry. Erect shrubs with leaves generally compound with 3 leaflets, the veins and leafstalks somewhat woolly. *Flowers solitary, crimson,* less than an inch in diameter. *Fruit red or salmon-color, thimble-shaped, pleasant to the taste.* From near San Francisco to Alaska.

c. **R. vitifo'lius Cham. & Schl.** BLACKBERRY. Stems trailing, very prickly. Leaves compound with 3–5 leaflets; the veins beneath, the leafstalks, peduncles, and sepals prickly. Flowers white, a half inch in diameter. *Fruit black when ripe, oblong, sweet.* Widely distributed.

d. **R. leucoder'mis Dougl.** Shrub with ascending and recurved stems, 3–5 ft. long, pale green, prickly. *Leaves with 3–4 leaflets, which are ovate-lanceolate, pointed and doubly serrate, pale green on the lower surface.* Flowers few. Sepals narrowed to a long point, surpassing the white petals. *Fruit black, generally covered with a bloom.* This is found from northern California to Washington.

XII. RO'SA, Wild Rose

Prickly and thorny shrubs. Leaves pinnately compound, leaflets serrate, stipules adnate to the petiole. *Receptacle globose, contracted at the throat.* Calyx of 5 divisions, without bractlets. Petals 5, rose-color. *Stamens many, near the mouth of the receptacle.*

a. **R. Califor'nica Cham. & Schl.** *Stems with stout recurved thorns.* Leaflets 2–3 pairs. Flowers in corymbs or rarely solitary. Fruit generally with a distinct neck beneath the spreading calyx lobes. This is widely spread throughout California, usually growing near streams.

b. **R. gymnocar'pa Nutt.** REDWOOD ROSE. Slender shrub covered with numerous straight prickles. Flowers generally solitary, less than an inch in diameter. *Calyx lobes generally falling from the fruit.* Pedicels, petioles, and stipules glandular. This dainty rose grows in the shade of trees or bushes, usually under the redwoods.

SUBORDER III. — POMEÆ

Trees or shrubs with stipules not attached to the petiole. Carpels 2–5, enclosed in and attached to the fleshy receptacle, becoming a fruit like an apple, of which the core is the ovary, and the fleshy part the receptacle (pome). Ovules 2 in each cell.

I. AMELAN'CHIER, Service Berry, June Berry

Shrub or small tree with deciduous leaves. Flowers large, white, in racemes. *Ovary 5-celled, becoming a part of the* *berry-like calyx, each cell partially divided by a partition from the back, 1-seeded.*

A. alnifo′lia Nutt. Leaves rounded, serrate towards the apex. Petals narrowly oblong, nearly an inch in length. Fruit, when ripe, purplish, edible. Rather widely distributed and variable.

II. CRATÆ′GUS, Thorn Apple

Trees or shrubs, with thorny branches. Leaves simple, toothed or lobed. Flowers white, in corymbs. Calyx tube urn-shaped, with a 5-parted border. Corolla of 5 white, spreading petals, about half an inch long. Stamens 5–20. *Ovary 2–5-celled. Fruit containing 2 or 3 bony seeds, either separated or united.*

C. Douglas′ii Lindl. Tree 10–25 ft. high, with thorns on the stems 1 in. long. Leaves broadly ovate, 1½–3 in. long, lobed or cleft and finely serrate. Corymb with many flowers. Fruit sweet and insipid, black. This blooms in the spring and is found from northern California to Washington.

III. HETEROME′LES (PHOTIN′IA), Toyon′, Christmas Berry

Shrub with evergreen, oblong, serrate leaves and minute stipules. Flowers white in close panicles at the ends of the branchlets, fragrant with a sweet, sickening odor. *Receptacle adnate to the ovary, becoming fleshy in fruit and nearly covering the 2 carpels, which are generally 1-seeded.*

H. arbutifo′lia Rœmer. Berries scarlet with mealy pulp, slightly astringent, but edible. In bloom chiefly in July and August; in fruit in November and December. Common in the Coast Mountains.

IV. PY′RUS (MA′LUS), Pear, Apple

Trees or shrubs, with deciduous leaves which are simple or pinnately compound, serrate. Flowers in corymbs, white or pink. Calyx top-shaped with the border 5-cleft. Petals 5, spreading. Stamens 20. Styles 5, more or less united at base. *Fruit a pome, the 5 cartilaginous carpels forming the core, and the calyx tube becoming a fleshy covering.*

P. rivula'ris Dougl. Tree 15–25 ft. high. Leaves simple, ovate-lanceolate, acute or pointed, 1–3 in. long, sometimes lobed or with sharp teeth on the margins. Corymb somewhat like a raceme. Pedicels slender, 1 in. long. Petals orbicular, white, $\frac{1}{3}$ in. long. Fruit reddish or yellowish, $\frac{1}{2}$ in. long. This is found from northern California to Washington.

V. SOR'BUS, Mountain Ash, Rowan

Shrubs or trees. *Leaves large, pinnately compound, with oblong, serrate leaflets.* Flowers small, white, in terminal, compound cymes. Styles distinct, as many as the cells of the ovary. Fruit about the size of a pea, red when ripe, usually containing one seed.

S. occidenta'lis Greene. Shrub 2–6 ft. high, smooth. Leaflets 3–5 pairs. Cyme small, with few flowers. Fruit pear-shaped. This grows in the Sierra Nevada Mountains, chiefly northward.

LEGUMINO'SÆ. Pulse Family

Ovary 1-celled; fruit a legume (*f.* Fig. 271, II; *e.* Fig. 176). Leaves alternate, compound, with stipules (with a few exceptions). There are three subdivisions, of which two are well represented in California.

Suborder I. — PAPILIONACEÆ, Pea Family

Calyx of 5 sepals, more or less united, often somewhat irregular. Corolla of 5 petals, papilionaceous (*f.* Fig. 141; *e.* Fig. 119). Stamens 10, either monadelphous, diadelphous, or distinct. Seeds 1 or several, without endosperm.

I. THERMOP'SIS, Golden Pea

Herb with spreading underground stems. *Leaflets 3, palmate, with stipules almost as large.* Flowers large, *yellow,* in terminal many-flowered racemes on short pedicels with bracts. *Stamens distinct from each other.* Legumes linear, compressed.

a. **T. Califor′nica Wats.** Silky-tomentose. *Leaflets an inch or two long, obovate;* stipules ovate or lanceolate, often longer than the petioles. Pods 1–2 in. long, erect and slightly spreading, with but few seeds maturing. This is the common species in California. It grows among the hills of the Coast Mountains where the ground is wet but not marshy, and blooms in spring.

b. **T. monta′na Nutt.** Silky-hairy. *Leaflets oblong, 1–3 in. long;* stipules ovate or lanceolate, generally longer than the petioles. Pods strictly erect, 2–3 in. long. This is found in the mountains of Washington and Oregon. It blooms in the spring.

II. PICKERIN′GIA (XYLOTHER′MIA), Spiny Chaparral, Chaparral Pea, Needle Bush

A very spiny glaucous shrub with small evergreen leaves. Leaflets from 1 to 3, without stipules. *Flowers large, solitary, nearly sessile in the axils of the leaves,* of a rich crimson color. It fruits very rarely.

P. monta′na Nutt. This is the only species. It is the most difficult chaparral of all to penetrate because of its stout spines. It is found on dry hills in the Coast Mountains.

III. LUPI′NUS, Lupine, Sun Dial

Calyx generally 2-lipped. Corolla with broad standard and wings united above, enclosing the incurved, pointed keel. *Stamens monadelphous in 2 sets. In the bud one set has long anthers, the others are shorter and tipped with a yellow ball.* As the flower develops, the ball-tipped filaments grow longer and push the pollen up to the top of the keel, from which the pistil projects. *Leaves palmately compound,* with the leaflets folding at mid-day. Stipules adnate to the petiole. Flowers in terminal racemes, sometimes arranged in whorls on the peduncles. The flowers are generally blue; but white and yellow-flowered species exist, also one combining yellow and rose-color.

a. **L. Chamisso′nis Esch.** Shrubby, pale green from the close white pubescence. Leaflets 7–9, silky on both sides. Flowers somewhat whorled, blue, violet, rarely white. This is variable, and several species have been included under this name; but they are not easily defined. Throughout California.

b. **L. arbo′reus Sims.** Shrubby, 4–10 ft. high. Leaflets 7–11, generally 9. Flowers generally yellow, in whorls, fragrant. This grows on sand-hills along the coast, where it is abundant and very showy in summer.

c. **L. trunca′tus Nutt.** Annual, erect, simple or branching above. finely pubescent, becoming smoothish. *Leaflets 5–7, linear-wedge-shaped, with the apex obtuse, truncate, 3-toothed or entire.* Flowers small, deep purple, rather scattered on the elongating raceme. Pods more than an inch long. Common in southern California. Spring.

d. **L. latifo′lius Agardh.** Perennial, stout, branching, 2–4 ft. high, leafy, dark green. Leaflets 5–7, oblanceolate, 1–2 in. long. Racemes long on slender peduncles. *Flowers rarely whorled, violet-blue, turning brownish in fading.* This is a common species in shady places of the Coast Mountains. Spring.

e. **L. microcar′pus Sims.** Annual, with many spreading branches from near the base, *woolly throughout.* Leaflets 9, 1 in. long or more, narrowly obovate. Racemes containing many whorls of purplish flowers and persistent bracts. Peduncles short, stout, somewhat succulent, often horizontal, and with the whorls turned to the upper side. Flowers rather large, on short pedicels. *Pods thick, 2-seeded.* This is common throughout California.

f. **L. densiflo′rus Benth.** This is very similar to the preceding, but is stouter and more spreading, less hairy, *with the racemes on long peduncles and the flowers white or yellowish,* rarely rose-color. This also is common and widely distributed.

(There are many other species not so readily recognized from descriptions, and many of them are quite local.)

IV. TRIFO′LIUM, Clover

Low herbs with palmately compound leaves of 3 leaflets, stipules adnate to the petiole. *Flowers in close head-like clusters on axillary peduncles.* Calyx with 5, nearly equal teeth. Petals with claws attached to the tube of the filaments. Stamens usually diadelphous (9 and 1). *Legumes small, from 1 to 6 seeded, usually enclosed in the calyx.* The species are numerous and difficult.

V. MELILO′TUS, Sweet Clover

Leaves pinnately compound of 3 toothed leaflets. *Flowers small, in slender racemes.* Legumes roundish, 1 or 2 seeded.

The entire plant is very fragrant. The two species are introduced.

a. **M. Ind′ica Allioni.** Flowers yellow, common.
b. **M. al′ba Lam.** Flowers white. Less common.

VI. MEDICA′GO, Bur Clover, Alfalfa

Leaves pinnately compound, of 3 leaflets. *Flowers in small clusters or racemes in the axils of the leaves. Legumes curved or curled like a screw.* The species are introduced and are valuable as fodder.

a. **M. denticula′ta Willd.** Bur Clover. Annual, low, with stems spreading on the ground, smooth throughout. Flowers small, yellow. *Pod coiled, armed with a double row of prickles.* Common.

b. **M. sati′va L. Alfalfa, Lucerne.** Perennial, erect, smooth. Flowers violet in a close raceme. *Pod spirally coiled, without prickles.* Usually escaped from cultivation.

c. **M. apicula′ta Willd.** This is similar in appearance to *M. denticulata, but the pods have the margins rough with fine tubercles instead of with hooked prickles, and the whole surface veiny.* In some places this is more common than *M. denticulata.*

VII. HOSACK′IA (LOTUS)

Stamens diadelphous (9 and 1). Petals with long claws, free from the stamens. Leaves pinnately compound with from 2 to many leaflets. Flowers solitary or in umbels, sessile or on peduncles from the axils of the leaves. *Legumes linear, sessile, somewhat compressed between the seeds.*

a. **H. Purshia′na Benth.** Annual, erect or spreading loosely over the ground, with numerous slender branches, soft woolly throughout. Leaflets generally 3 on a linear rhachis. *Flowers solitary, salmon-color, axillary on slender peduncles which are longer than the leaves, with a single leaflet below the flower.* Legumes from 1 to 1½ in. long. This is common, blooming in the summer and autumn. Widely distributed.

b. **H. subpinna′ta T. & G.** Stems low, spreading or erect, smooth or woolly. *Leaflets small, 3–5, on a dilated rhachis; stipules gland-like. Flowers small, nearly or quite sessile in the leaf axils, without bracts.* Pod ½ in. or more in length with about 5 seeds. From Santa Barbara to Washington, common.

c. **H. parviflo'ra Benth.** Annual, with slender, smooth stems. Leaflets 3–5. *Flowers very small, yellow, but becoming red with age; peduncles thread-like, each with a 1–3-leaved bract.* Pods linear, contracted between the seeds; these 5–7. This is common from middle California to British Columbia. Spring.

d. **H. gra'cilis Benth.** Perennial with slender stems, generally spreading over the ground and growing in wet places. Leaflets 5–7; stipules thin. Umbels with 8–10 flowers about as long as the leaves, with a 3-leaved bract. Calyx teeth shorter than the tube. *Corolla with yellow banner, rose-red wings and keel.* Pods long and straight. This is the most beautiful species, and it is found from Monterey to Washington.

e. **H. bi'color Dougl.** Perennial with smooth, erect, rather stout stems. Leaflets 5–7, obovate or oblong; stipules papery, rather large. Peduncles longer than the leaves; umbel of 3–7 flowers, with or without a bract. *Flowers nearly sessile, yellow, or with white wings.* Calyx teeth half as long as the tube. This grows in wet ground and is found from near San Francisco to Washington.

f. **H. gla'bra Torr.** *Somewhat shrubby, with many nearly smooth, erect, or decumbent stems from the root.* Leaves few, with 3 small leaflets. *Umbels numerous, sessile along the stem, consisting of many yellow flowers that become reddish.* Legumes curved and tipped with the long style. This is common all over the state, and in bloom at all seasons. There are many other species more difficult to distinguish.

VIII. PSORA'LEA

Ill-scented herbs covered with dark, glandular dots. Leaves with 3–5 leaflets and stipules free from the petiole. *Flowers white or purplish in axillary spikes or racemes, with thin bracts that soon wither and fall. Legumes sessile, 1-seeded, indehiscent.*

a. **P. orbicula'ris Lindl.** *Stems running along the ground in swampy places, bearing leaves and spikes of flowers on petioles and peduncles a foot or more long.* Leaflets large, round. Flowers large, purple, in close, woolly spikes. Stamens diadelphous (9 and 1). Throughout California.

b. **P. macrosta'chya DC.** *Stems usually very tall, 6 ft. or even more.* Leaves ovate-lanceolate. *Peduncles much longer than the leaves.* Spikes silky-woolly, with blackish hairs on the calyx. Bracts broad. Corolla purple. *The tenth stamen almost free.* Legumes woolly. Throughout California, along streams.

c. **P. physo'des Dougl.** *Generally a foot or two high, with several stems spreading from the base.* Flowers in short, close racemes.

Calyx becoming slightly inflated in fruit. *Corolla yellowish white, tinged with purple.* Stamens monadelphous. In the Coast Mountains from Monterey County to Puget Sound.

IX. ASTRAG'ALUS, Rattleweed, Loco-weed

Herbs with odd-pinnate leaves and numerous leaflets. Flowers in racemes or spikes, on axillary peduncles. Stamens diadelphous (9 and 1). *Keel of the corolla blunt at tip. Legumes numerous, more or less 2-celled by one or both sutures projecting inwards, often inflated like a bladder so as to secure dispersion of the seed by the wind.* Several species are poisonous to cattle and sheep. Almost all are perennials. The species are numerous and too difficult for beginners.

X. VIC'IA, Vetch

Vines, with the leaves terminating in tendrils. Stipules semi-sagittate. Flowers solitary or in loose axillary racemes. *Stamens diadelphous. Stigma a round hairy ball at the tip of the slender style.* Legumes similar to those of the common pea.

a. **V. gigante'a Hook.** Perennials, stout, climbing high over the bushes. Leaflets from 10 to 15 pairs. Corollas reddish or dirty white, turning brown. *Pods becoming black when ripe, each seed encircled by its stalk.* This is common in moist places from San Francisco northward.

b. **V. America'na Muhl.** Pea Vine. Perennial, generally low. Leaflets from 4 to 8 pairs, linear, generally truncate or toothed at apex. *Flowers bluish, in few-flowered racemes.* Legumes smooth. Seeds 3–6, dark purple. Widely distributed.

XI. LATH'YRUS, Wild Pea

This is similar to *Vicia*, except that the tendrils are absent in some species, the flowers are larger, the leaflets broader, and, most important, *the style is hairy not only at the tip, but also down the inner side.*

The species are difficult to distinguish.

Suborder II. — CÆSALPIN'EÆ

Flowers more or less irregular. Corolla not truly papilionaceous, with the petal that answers to the standard folded within those on the side. Stamens 10 or fewer, distinct. Seeds sometimes with endosperm.

CER′CIS, Red-bud, Judas-tree

A small tree or shrub, blooming before the leaves appear. Leaves cordate to kidney-shaped, entire, palmately veined. *Flowers bright rose-color, in axillary clusters, numerous on the leafless stems.* Petals 5, the standard enclosed by the wings. *Pod large, flat and thin, turning purplish.*

C. occidenta′lis Torr. This is the only native species on the Pacific Coast. It is most beautiful along mountain streams throughout California, but not near the seacoast.

SUBORDER III. — MIMO′SEÆ

Flowers regular, small, and numerous in spikes or heads. Calyx and corolla of 4 or 5 divisions. Stamens as many or twice as many as the petals, or numerous, inserted on the receptacle.

ACA′CIA

Flowers small, numerous in spikes or heads. Stamens very numerous. Flowers usually yellow (rarely rose-color).

Leaves various, naturally pinnately compound, but in many Australian species reduced to a petiole flattened and broadened like a leaf (phyllodia). On young plants the gradations between the compound leaf and the simple phyllodia can often be seen.

GERANIA′CEÆ. GERANIUM FAMILY

Herbs with pungent, acid, or aromatic juice. Sepals and petals 5. Stamens 5 or 10.

The fruit consists of 5 distinct carpels around a central column, or is a 5–10-valved capsule splitting so as to shoot out the seeds.

I. GERA′NIUM, Crane's Bill

Annual or perennial herbs with large joints and palmately lobed leaves, stipules papery. Style 5-lobed at the summit.

Fruit of 5 carpels, which separate when ripe from the axis, each one with a long, beardless tail, which curls from the bottom of the axis to the summit. Most of the plants cultivated as geraniums belong to the genus *Pelargonium.*

a. **G. inci′sum Nutt.** Perennial, with branching, leafy stems, with glandular and hairy pubescence. *Flowers large*, axillary, on pedicels that are spreading or reflexed in fruit. *Petals purple, woolly on the inner surface.* Filaments woolly. *Fruit with the beak glandular.* Common in the Sierra Nevada Mountains and extending to Washington and Oregon. It blooms in spring and summer.

b. **G. Richardson′ii F. & M.** This is somewhat similar to the preceding, and like it, is perennial. The stems are taller, more slender, and weaker. The flowers are smaller, and always white, though there may be pink veins on the petals. It grows in wet places in the mountains at rather high elevations.

c. **G. Carolinia′num L.** Annual, with spreading stems, and gray, somewhat glandular pubescence. *Flowers and leaves closely clustered at the ends of branchlets, the former small, rose-color*, the latter orbicular in outline, but cut into several divisions. *Carpels covered with black hairs*, beak woolly or glandular. Common and widely distributed.

d. **G. dissec′tum L.** Greener than the preceding, and with *the leaves cut into narrower and more numerous divisions.* Stems weak, often supported on other plants, and frequently growing in wet places. Common, introduced.

II. ERO′DIUM, Alfilerilla, Filaree′

This is similar to *Geranium;* but the filaments are broader, and those opposite the petals are without anthers, *the tails of the carpels are bearded on the inner side, and when they break away from the axis they form a spiral.* The flowers are usually in umbels with an involucre of 4 bracts, and the petals are small and fall easily.

a. **E. cicuta′rium L'Her.** Red-stemmed Filaree. Leaves forming a rosette at the base of the stem, compound with many leaflets, which are cut into numerous, narrow, acute lobes; the stem leaves are small, and shorter than the peduncles. Flowers rose-purple, 4–8 in an umbel. The axis on which the carpels are arranged is from 1 to 2 in. long. This is the commonest and most valued "filaree."

b. **E. moscha'tum L'Her.** GREEN-STEMMED FILAREE. *This has a faint odor of musk.* The root leaves form a cluster, but are larger and coarser than the preceding, and erect, often a foot long. The leaflets are doubly serrate. This always has a greener and more luxuriant appearance than the preceding. Widely distributed.

c. **E. Bo'trys Bert.** Stems short, depressed. Leaves in a rosette, reddish and shining, oblong in outline with coarsely-toothed segments. Petals lilac-purple, longer than the calyx, forming a bell-shaped corolla. Carpels with beaks 2–4 in. long. This gives a reddish color to the hills along the seaboard in early spring. The long beaks of the akenes are conspicuous later. It is introduced, and likely to be found everywhere along the coast.

d. **E. macrophyl'lum H. & A.** Stems very short, glandular-hairy above. *Leaves kidney-shaped, crenate-serrate.* Petals white, as long as the sepals. This is found chiefly in clayey soil, and is widely distributed.

III. LIMNAN'THES, Meadow Foam

Smooth, succulent annuals with pungent juice. Leaves alternate, without stipules, pinnately cleft. Flowers showy, solitary, on axillary peduncles, white, yellowish, or rose-color. Petals convolute in the bud. Stamens 10. *Carpels at first fleshy, becoming hard and wrinkled, separating from the short axis.* This grows always in wet places.

a. **L. Douglas'ii R. Brown.** Stems very smooth, brittle, much branched. Peduncles 2–4 in. long. Sepals lanceolate, petals twice as long, yellow, white, or of both colors, obovate, emarginate. This beautiful plant sometimes covers large areas in wet meadows. Throughout California.

b. **L. ro'sea Hartw.** Leaves with narrow linear lobes; flowers white, turning rose-color. This is found in the great valleys of California.

c. **L. al'ba Hartw.** Short and stout, with the leaf segments broad, short, 3-lobed. Petals white, not much longer than the densely woolly sepals. Northern California.

IV. OX'ALIS, Wood Sorrel

Low herbs with acid juice, often without a stem. Leaves compound with 3 obcordate leaflets, like clover. Stamens 10, with filaments dilated and united at the base. *Capsule beaked with the short style, 5-celled with the valves remaining attached to the axis by the partitions.*

a. **O. Orega'na Nutt.** Wood Sorrel. Perennial herbs forming mats, with slender rootstocks from which arise the leaves and flowering stems. Leaflets broadly obcordate, rusty underneath. Scapes usually 1-flowered, with 2 bracts near the flower. *Petals nearly an inch long, pink, white, or rose-color with darker veins.* This is common in the redwood forests of the coast, north to Washington.

b. **O. cornicula'ta L.** Yellow Sorrel. This also often forms mats with slender prostrate stems. Leaflets deeply obcordate. *Peduncles bearing 2 or more flowers with yellow petals.* The reddish-leaved, yellow-flowered sorrel, which is a common weed in the streets and gardens, is a variety of this species.

LINA'CEÆ. Flax Family

Flowers with all parts 5, except the pistil. Sepals persistent, imbricated. Petals convolute in the bud, falling soon. Each division of the ovary contains a pair of seeds.

LI'NUM, Flax

Herbs with tough fibers in the bark. Leaves sessile, entire. Styles 2–5. Ovary globose, with as many true cells as styles, each cell partially separated into two false cells. The capsule splits through the false and true partitions, each half cell containing one seed. The species are rather local and with one exception small-flowered.

L. Lewis'ii Pursh. Perennial, with erect, leafy stems, smooth and bluish green. Leaves generally linear, an inch or less long, without stipules. Flowers azure blue, nearly an inch in diameter, in racemes or corymbs on elongating pedicels. Pod longer than the calyx, 10-celled and 10-valved, with the valves widely spreading when ripe. Common and widely distributed, blooming in spring and summer.

The introduced flax, **L. usitatis'simum L.**, is somewhat similar, but is an annual. There are many small-flowered, annual species in California, but they are difficult to distinguish and are more or less local.

POLYGALA'CEÆ. Polygala Family

Herbs or shrubs with simple, entire leaves without stipules. Flowers superficially resembling a pea blossom. Stamens united into one or two sets, adnate to the petals; anthers 1-celled, opening at the top.

POLYG′ALA

Sepals 5, two of them large and spreading like wings. Petals 3, united to each other and to the stamen tube, the middle one forming a hood. Stamens 6–8, with filaments united into a tube, split down one side. Pod notched, flattened contrary to the partition, 2-celled, with one seed in each cell.

a. **P. cornu′ta Kellogg.** Low shrub with slender stems and branches, 1–6 ft. high. Leaves oval, obtuse, on very short petioles. *Flowers greenish white tinged with rose-color*, in short racemes. Outer sepals usually finely tomentose. Petals shorter than the keel, which is tipped with *a straight beak.* Pod orbicular with the apex notched. This grows in the pine woods through the Sierra Nevada.

b. **P. Califor′nica Nutt.** Low perennial with slender, woody stems rising 2–8 ft. from creeping rootstocks. Flowers in terminal racemes. Sepals nearly smooth. *Petals purple*, with the wings longer than the keel, which has *a recurved beak. The fruit is chiefly from flowers without petals near the root.* The pod is smooth and almost orbicular. This is common in the Coast Mountains of California and extends to Oregon.

EUPHORBIA′CEÆ. Spurge Family

Herbs with milky juice which is sometimes poisonous. Leaves simple with stipules. Flowers monœcious or diœcious, naked or apetalous. Stamens 1 to many. Pistil 1, with a 3-lobed ovary and 6 styles or stigmas. Pod dehiscing with an elastic movement that scatters the seeds, leaving the axis.

I. EUPHOR′BIA, Spurge, Milkweed

Flowers monœcious, both *the staminate and the pistillate included in a cup-shaped involucre which might be mistaken for a calyx.* Staminate flowers numerous, each of a single stamen on a short, jointed pedicel with a tiny bract at base. Pistillate flowers solitary, hanging on a long pedicel from the center of the involucre. *Ovary with one ovule in each cell;*

styles 3, each with 2 stigmas. Involucre 4–5-lobed, the lobes alternating with crescent-shaped or colored and petal-like glands.

a. **E. albomargina′ta Torr. & Gray.** Stems numerous, forming a prostrate mat. *Leaves small, almost round, cordate with a narrow whitish edge.* Stipules united into a triangular, white, membranous scale. Glands of the involucre 4, brownish orange with white or rose-color, petal-like appendages with entire margins. Seeds 4-angled. This grows in southern California.

b. **E. serpyllifo′lia Pers.** Annual with prostrate or ascending stems, smooth. *Leaves with the base unequal,* oblong, 1–6½ in. long, the margins with some very fine teeth. Stipules bristle-like or ragged. Involucres generally solitary. Seeds 4-angled, somewhat pitted. The glands are small and the margins narrow, whitish, crenate. This is widely distributed and is often found along roads and railroad tracks. It blooms in summer and turns reddish towards fall.

c. **E. crenula′ta Engelm.** Annual or biennial, erect with one or several leafy stems from the root, generally branching above with 2-forked branches. Leaves about an inch long, spatulate. *Involucres with crescent-shaped glands and no petal-like appendages.* Seeds gray, covered with dark-colored pits. This blooms early and is widely spread.

II. EREMOCAR′PUS, Turkey Mullein, Yerba del Pescado

Stems branched from the base, prostrate, forming a mat. Flowers monœcious, clustered in the axils of the leaves without an involucre. *Staminate flowers with a 5 or 6 parted perianth; pistillate flowers, naked. Capsule 1-celled and 1-seeded.*

E. setig′erus Benth. Grayish green, covered with white hairs and a stellate pubescence. Leaves 3-nerved, ovate, obtuse, round at base, on long petioles. Flowers inconspicuous. This is called "turkey mullein" because turkeys are fond of the seeds. The name given by the early settlers is "yerba del pescado" because it was used by the Indians in catching fish. The effect of the leaves thrown into a fish stream is to stupefy the fish so that they can be caught by hand. Common in middle California and inclined to cover waste places. Summer and fall.

ANACARDIA'CEÆ. Poison Oak Family

Shrubs or trees with leaves alternate, without stipules, either simple or compound. Flowers small, regular. Stamens inserted on the inner margin of the disk. Ovary 1-celled, 1-ovuled. Styles often 3. Fruit a small drupe.

RHUS, Sumac, Poison Oak

Sepals and petals (4–9) generally 5. Stamens as many or twice as many. Sterile and fertile flowers often mixed in the clusters. Only the first species is poisonous.

a. **R. diversilo'ba T. & G.** Poison Oak. Stems shrubby or climbing by rootlets. *Leaves compound with 3 leaflets, which are 3-lobed and coarsely toothed or entire.* Flowers yellowish white, fragrant, in loose panicles in the axils of the leaves. Fruit a round, white, nerved, smooth berry. This is most poisonous in the spring. It generally forms thickets. The foliage turns red in the fall.

b. **R. triloba'ta Nutt.** Squaw Bush, Indian Lemonade. An aromatic shrub with numerous, spreading branches. Leaves somewhat variable, with 3 leaflets, the middle one 3-lobed and toothed, much larger than the 2 side leaflets, which are generally simple and crenate. *Flowers greenish, in short spikes, which precede the leaves. Fruit a red berry, pleasantly acid.* Seeds white and smooth. Widely distributed, but not especially common.

c. **R. integrifo'lia Benth. & Hook.** Shrub or small tree. Leaves many, evergreen, thick, oval, entire or with spiny teeth, dark green and glossy above, sometimes compound. Flowers rose-color, in clustered spikes. *Fruit covered with an acid, viscid coat; the berry about ½ in. long.* This is found in southern California near the sea.

d. **R. ova'ta Wats.** Similar to the above, but with larger, thinner leaves, which are ovate or almost heart-shaped; *fruit having the viscid coat crusted with a white powder.* This is found in the mountains of southern California.

e. **R. lauri'na Nutt.** Shrub with oblong-lanceolate, entire leaves on rather long petioles. Flowers many in a terminal panicle, small, white. *Fruit smooth, whitish, beaked by a stout style.* This grows in southern California near the coast.

Schi'nus mol'le L. Pepper Tree. This is extensively cultivated. It is an evergreen tree, with graceful, drooping branches and compound leaves, with 20 or more pairs of narrow leaflets. The flowers are small, diœcious, in large panicles, with 5 greenish petals and 10 stamens. The fruit consists of numerous pungent rose-color drupes as large as dry peas.

SAPINDA′CEÆ (including Buckeye and Maple)

Trees or shrubs with deciduous simple or compound leaves without stipules. Sepals 5, often irregular, and more or less united. Petals alternate with the sepals or wanting. Stamens more than 5. Ovary with 2 ovules in each cell, often only one maturing.

I. ÆS′CULUS, Buckeye

Leaves opposite, palmately compound, of 5-9 leaflets. Flowers white or pale rose-color, in a panicle nearly a foot long; very few are fertile, the majority being staminate. Calyx tubular. Petals 4 or 5, with long claws. Ovules 6, 2 in each cell of the ovary; but generally only one ripening, *becoming a large chestnut-like seed which is covered with the three leathery valves of the capsule.* The abortive seeds can all be seen within the capsule.

Æ. Califor′nica Nutt. This is a low-spreading tree or, rarely, a shrub. The leaves fall very early, leaving the pods hanging on long, naked peduncles. Rather widely distributed through middle California.

II. AC′ER, Maple

Trees or shrubs with deciduous *palmately lobed leaves.* Petals as many as the sepals, and inserted with the stamens on the margin of the disk. *Fruit of 2, winged carpels.*

a. **A. macrophyl′lum Pursh.** Large-leaved Maple. This grows to be a large tree with leaves from 6 in. to nearly a foot broad. *Flowers yellowish, fragrant, in drooping racemes.* Fruit densely hairy, with wings obliquely spreading. This grows along streams. From Santa Barbara to British Columbia.

b. **A. circina′tum Pursh.** Vine Maple. Shrubs or small trees with trailing stems that strike root where they touch the ground, forming thickets. *Flowers in loose, umbel-like corymbs.* Fruit smooth, with wings horizontally spreading. Northern California to British Columbia.

III. NEGUN′DO, Box Elder

A small tree, *with leaves pinnately compound with 3 leaflets.* Flowers diœcious, apetalous. Staminate flowers in umbels with very slender pedicels. Fertile flowers in drooping racemes. Fruit of 2, winged carpels with wings almost parallel.

N. Califor′nicum Torr. & Gray. This grows along streams in the Coast Mountains, but is not very abundant.

RHAMNA′CEÆ. Buckthorn Family

Shrubs or trees with simple leaves and small flowers. Calyx valvate in the bud. Stamens opposite the petals. Ovary with from 2 to 4 cells. Stigmas with as many lobes as there are cells to the ovary. Seed solitary in each cell.

I. RHAM′NUS, Coffee Berry, Cascara Sagrada

Leaves alternate, with stipules that soon fall. Calyx tube urn-shaped with a 4 or 5 cleft margin. Petals very small or none. *Ovary a drupe containing 2 or 3 stones.*

a. **R. cro′cea Nutt.** *Leaves evergreen, almost orbicular, small, shining above, inclined to be yellow beneath, sharply toothed.* Flowers with the parts in fours. *Berries red.* Throughout California.

b. **R. Califor′nica Esch.** *Leaves evergreen,* 1–4 in. long, ½–2 in. wide, elliptical, denticulate, or nearly entire. *Fruit black-purple, 2-seeded.* Throughout California.

c. **R. Purshia′na DC.** This sometimes becomes a tree. *Leaves deciduous,* elliptical, pubescent beneath, 2–7 in. long, 1–3 in. wide. Petals cleft at the apex. *Fruit black, 3-seeded.* This is more common in northern California and extends to British Columbia.

II. CEANO′THUS, California Lilac

Trees, or more often shrubs, with small, simple leaves. Flowers small, blue or white, in cymes or panicles. Calyx bell-shaped, with colored margin. Petals with a small claw, the blade forming a hood. Ovary half immersed in the disk, style 3-cleft. *Fruit a 3-seeded capsule embraced at the base by the calyx tube, dehiscent from the junction of the 3 cells* with elasticity sufficient to scatter the hard nutlets.

a. **C. thyrsiflo'rus Esch.** Blue-blossoms. A tall shrub or tree with small alternate leaves, 3-nerved from the base. *Flowers dense in numerous, compound racemes, often forming a thyrse, light blue, very fragrant.* This is one of the most beautiful plants when in bloom. It frequently covers places where the redwoods have been [illegible] burned. From Monterey County northward.

b. **C. veluti'nus Dougl.** This is a stout, diffusely branched shrub. *Leaves alternate, large, thick, resinous, and shining on the upper surface, aromatic, strongly ribbed from the base. Flowers white,* in loose clusters on short peduncles. Common in northern California and Oregon.

c. **C. integer'rimus H. & A.** Tall, erect shrub without spines. Leaves alternate, *3-nerved*, ovate, soft-hairy on both surfaces, on short petioles. *Flowers white or blue in slender panicles. Pods nearly smooth with the crests on the sides.* Through California in the mountains, to Washington. In some places it is known as red-root.

d. **C. divarica'tus Nutt.** *Tall shrub with olive or bluish-green branchlets.* Leaves alternate, ovate, 3-nerved, colored like the twigs but with the upper surface darker. *Flowers pale blue, in ample panicles.* Pods smooth, *scarcely crested.* The stems are rigid and frequently spiny. This is common in southern California.

e. **C. inca'nus T. & G.** Shrub with stiff, spiny, diffusely branched stems. Leaves alternate, large, elliptical to ovate, pale green, 1–2½ in. long. Flowers in short, dense, axillary clusters, frequently forming a thyrse. *Pod very resinous, lobed at top.* This is found in the Coast Mountains of middle California.

f. **C. cordula'tus Kellogg.** Snow-bush. Low shrubs, generally with flat tops; stems with spreading branches gray or glaucous. *Leaves alternate, elliptical to orbicular,* generally obtuse at base, denticulate at apex, pale gray-green on the lower side, darker above. Flowers white, small, in numerous small clusters all over the stems. *Capsules smooth, slightly crested.* This forms thickets in the mountains of California and Oregon.

g. **C. folio'sus Parry.** Low shrub with declined or trailing branches. *Leaves alternate, small, with glandular, revolute margins.* Flowers dark blue or rarely white, in small, numerous clusters all over the stems. This blooms profusely soon after the rains and is in bloom almost continually. Common in the Coast Mountains.

h. **C. soredia'tus H. & A.** Erect shrub, becoming tree-like, with spreading, rigid branches, somewhat thorny. *Leaves alternate, elliptical, glandular on the margins, gray-green on the lower surface, darker above.* Flowers deep blue, small, in very numerous, small, oblong clusters. This is found in the Coast Mountains, and is a most beautiful sight in full bloom.

i. **C. cunea'tus Nutt.** *Widely branched with rigid branchlets. Leaves opposite, spatulate or wedge-shaped, on very short petioles, paler on the lower surface in lines.* Flowers in small umbels which are close together on the branches, white or lavender. *Pods with 3 erect horns or crests.* This is common throughout California to Oregon.

j. **C. crassifo'lius Torr.** Erect shrub with rigid branches, the [illegible] twigs clothed with white down. *Leaves opposite, thick, white-downy on the lower surface, obtuse or retuse at apex.* Flowers in numerous clusters on short peduncles, light blue or white, very densely clustered. *Capsule with 3 horn-like crests below the summit.* This is found in the Coast Mountains, especially in southern California.

k. **C. pineto'rum Coville.** Low shrubs with flat tops and many stiff, spreading branches. *Leaves opposite, thick, glossy on the upper surface, coarsely toothed.* Flowers blue or white, rather large, in many small clusters. *Capsules large, red, with large, erect horns near the apex and with crests between.* On dry hills in the Sierra Nevada and Coast Mountains.

l. **C. prostra'tus Benth.** Squaw-carpets, Mahala Mats. *Stems forming mats, rooting.* Leaves opposite, thick, with sharp teeth on the margins, spatulate or wedge-shaped. Flowers blue, rather large. *Pods large, red, with 3 large, wrinkled horns at the apex and crests between.* Common in the mountains of California and extending to Washington.

MALVA'CEÆ. Mallow Family

Herbs or shrubs with flowers generally showy. Calyx with lobes valvate in the bud, often with an outer row of bracts below, resembling another calyx. Petals 5, united at the base of the stamen tube. Stamens numerous, united into a column by their filaments, enclosing the pistils. Anthers kidney-shaped, 1-celled, except in *Fremontia.* Fruit a 3–10-celled pod or a cluster of one- to several-seeded carpels, at the base of the united styles, commonly called "cheeses."

I. LAVA'TERA, Tree Mallow

Stout shrubs, frequently planted as wind-breaks. Leaves large, evergreen, 5–7-lobed. Flowers axillary, on long peduncles. *Calyx with an outer row of 3–6 leaflets.* Carpels 1-seeded.

L. assurgentiflo′ra Kellogg. This grows to a height of several feet, and has large reddish purple flowers, veined with darker lines.

II. SIDAL′CEA, Rose Mallow

Perennial or annual herbs. Leaves round in outline, lobed or parted. Flowers rose-color, in a terminal raceme or spike. *Calyx with outer bracts wanting.* Column of stamens double. Carpels 1-seeded, indehiscent.

a. **S. malvæflo′ra Gray.** Perennial with several stems from the root 1–2 ft. high, erect or ascending, hairy. Root leaves rounded, deeply crenate; stem leaves 7-parted, with the divisions 3-lobed. Flowers in spike-like racemes, rose-color. *Carpels becoming somewhat wrinkled and veiny when ripe.* There are two kinds of flowers. Those with rudimentary anthers are smaller and generally of a deeper color; the perfect flowers are an inch or more across. The pistils ripen after the pollen is discharged. This is variable and common near the coast.

b. **S. Orega′na Gray.** Perennial. Stems solitary or few from the root, 2–6 ft. in height, branching into panicles which are stellate pubescent. Leaves chiefly at the base, orbicular in outline, 7–9-lobed, the lobes cleft. Flowers ½–1 in. long in spicate racemes. *Carpels slightly beaked, smooth.* From northern California to Oregon.

c. **S. diploscy′pha Gray.** *Annual, with hairy stems* 1–2 ft. high; branches spreading. Leaves round-kidney-shaped, the earliest crenate, the others with 5–7 lobed divisions. Petals pink, an inch long. *Carpels veiny and wrinkled, depressed, beakless.* This is common in middle California in fields, growing like a weed. It is one of the most beautiful species.

III. MALVAS′TRUM

Erect shrubs or herbs. *Calyx with 3 outer bracts.* Stamen tube simple. Stigmas capitate. *Carpels 1-seeded, usually splitting from the top.*

a. **M. Par′ryi Greene.** *Annual. Stems prostrate or ascending.* Leaves deeply 5-parted, with toothed or lobed segments. Flowers axillary, on long, slender peduncles. Carpels 15–20. This is similar to *Sidalcea malvæflora* in the diœcious character of its flowers. The perfect flowers are often more than an inch in diameter. This is found in middle California in dry places.

b. **M. fascicula'tum Greene.** *A shrub 6–8 ft. high, with long, slender branches.* Leaves tomentose, 5-lobed, coarsely toothed. Flowers in racemes or panicles. Corolla rose-purple, $\frac{3}{4}$ in. long. Carpels smooth below, tomentose above. This is a beautiful shrub, or sometimes a tree, common in southern California.

IV. FREMON'TIA, Slippery Elm

A shrub or small tree, with small 3–7-lobed leaves, rusty stellate pubescent. Calyx 1–3 in. in diameter, 5-cleft almost to the base, with bright yellow, leathery divisions, imbricated in the bud; persistent bractlets under the calyx 3–5, small. Corolla wanting. Stamens 5, with filaments united to the middle. Anthers linear, 2-celled. Capsule 4 or 5 celled, dehiscent from the top. This is, by some authorities, put into *Sterculiaceæ.*

F. Califor'nica Torr. FALSE SLIPPERY ELM. This is a fine sight when in bloom. The large yellow flowers are numerous on the long stems. The fruit is densely hairy and woolly on the inside, and the dry open pods persist. The bark is used as slippery elm. From middle California to San Diego.

HYPERICA'CEÆ, ST. JOHN'S-WORT FAMILY

Herbs with opposite leaves, covered with transparent or dark dots or with both kinds. Flowers with 4 or 5 sepals, and as many petals. Stamens numerous in 3–5 clusters, on the receptacle. Styles 3–5, more or less united. Pod splitting at the partitions into 3 valves.

HYPERI'CUM, St. John's-wort

Flowers yellow. Stamens in several sets, stigmas capitate.

a. **H. Scou'leri Hook.** *Erect, with simple stems from running rootstocks.* Leaves oblong, obtuse, clasping, about an inch long. Flowers nearly an inch in diameter, in panicled cymes. This grows in moist places, chiefly in the mountains.

b. **H. concin'num Benth.** *Stems low, numerous, from a woody base. Leaves not clasping, usually folded, growing in four distinct ranks up* *the stem.* Stamens very numerous, in 3 sets. Corollas nearly an inch in diameter. This grows on dry hills in central California.

c. **H., anagalloi′des Cham. & Schl.** *Stems weak, low, spreading, rooting at the joints, growing in wet places and forming mats.* Leaves small, clasping. *Flowers small, in cymes.* Pod 1-celled. Widely distributed.

FRANKENIA′CEÆ, Yerba Reuma Family

Low, spreading, perennial herbs or shrubs, with opposite, entire leaves and no stipules. Calyx tubular, 4 or 5 lobed, ribbed. Petals with long claws inserted on the receptacle. Stamens 4–7. Ovary 1-celled. Fruit a 2–4-valved pod included in the calyx tube.

a. **Franke′nia grandiflo′ra Cham. & Schl.** Yerba Reuma. Stems very numerous, slender. Leaves numerous, small and narrow, with the margins rolled under. Petals small, pink. On account of the great amount of salt contained in this plant it is almost impossible to dry it. It is common in salt marshes on the coast.

b. **F. grandiflo′ra var. campes′tris.** This is the form found in the interior alkaline marshes.

CISTA′CEÆ, Rockrose Family

Calyx in 2 series; the outer sepals 2, smaller than the 3 inner, turned to the left in the bud, while the 5 petals are turned to the right. Stamens many, style 1. Fruit a capsule, with the parietal placentæ protruding towards the center.

HELIAN′THEMUM, Rockrose

Perennials, with many slender stems about a foot high from a woody root. Flowers small, yellow, open only in sunshine, with petals soon falling. Ovary opening into 3 valves.

H. scopa′rium Nutt. This grows on dry hills throughout California, in the Coast Mountains.

VIOLA′CEÆ, Violet Family

Low perennial herbs having alternate leaves with leaf-like stipules. Flowers on axillary peduncles. Sepals 5, persistent. Petals 5, one with a spur at base. Stamens 5, short, with the filaments cohering around the pistil. Style club-shaped, with a one-sided stigma. Pod 1-celled, splitting into 3 parts, each bearing seeds on the middle nerve. The seeds are often scattered by the bursting of the elastic valves.

VI′OLA, Violet

Sepals ear-like at the base. Petals somewhat bearded within, thus affording a foothold for bees, the lowest one with a spur at base. Stamens not cohering very much, the lowest with spurs which reach down into the spur of the lowest petal.

a. **V. palus′tris L.** Stemless, low, from thread-like creeping rootstocks. Leaves round-cordate, 1–2 in. in diameter, faintly crenate. *Flowers pale lilac to white, with short, rounded, sac-like spurs.* Northern California to Alaska, growing in swampy places in the mountains.

b. **V. cani′na var. adun′ca Gray.** Blue Violet. Stems leafy, several from the rootstock. Leaves simple, ovate-cordate, with leaf-like stipules. *Flowers blue, with the spur as long as the sepals. The side petals are bearded.* Widely distributed in the Coast Mountains.

c. **V. ocella′ta T. & G.** Heart's-ease. Stems leafy. Leaves heart-shaped, crenate, with small papery stipules. *Upper petals white within, dark on the outside; the others pale yellow, veined with purple; those on the sides with a purple spot near the base.* In woods from Monterey County northward.

d. **V. peduncula′ta T. & G.** Pansy. Stems leafy, with ovate leaves wedge-shaped at the base. Stipules narrowly lance-shaped. *Flowers large, on long peduncles, deep yellow.* Upper petals tinged with brown on the outside, the others veined with purple, those on the sides bearded. Common from southern to middle California.

e. **V. sarmento′sa Dougl.** Creeping Violet. *Stems creeping by leafy stolons.* Leaves finely crenate, round, with heart-shaped base. *Flowers light yellow.* This grows in the woods of the Coast Mountains.

f. **V. præmor′sa Dougl.** Stems short, frequently underground, gray pubescent or smooth. *Leaves ovate-lanceolate, with the margin sinuate to dentate, tapering to the petiole.* Sepals papery, entire or slashed. *Petals yellow, generally tinged with brown on the outside.* Ovary globular, pubescent. Variable and widely distributed.

g. **V. loba′ta Benth.** Stems leafy. *Leaves palmately cut into 5–9 narrow lobes, the central one the longest.* (The root leaves are sometimes simple with crenate margins.) Stipules large, leaf-like. *Flowers yellow.* Upper petals brownish purple on the outside, the others veined or tinged with purple, the side petals slightly bearded. Throughout California.

h. **V. chrysan′tha Hook.** Apparently stemless. *Leaves round in outline, twice divided into linear segments.* Stipules lance-shaped. Flowers on peduncles as long as or longer than the leaves, bright yellow. *Lower petals veined, yellow; the upper brownish purple on the outside;* the side petals not bearded. On low hills from Monterey County northward.

i. **V. trinerva′ta Howell.** Stemless, smooth. *Leaves palmately 3–5-parted with lanceolate, acute divisions;* stipules small, entire, almost free. *Upper petals deep blue or violet; lower yellow.* Washington.

j. **V. Beckwith′ii T. & G.** Stemless, hairy or almost smooth. Leaves orbicular, *palmately 3-parted into linear, obtuse divisions. Upper petals deep blue or violet, lower light blue or white, with the base yellowish.* This is found from northern California in the Sierra Nevada to Oregon, generally on the eastern slope.

MYRTA′CEÆ, Myrtle Family

Eucalyp′tus. There are many different species of this genus cultivated in California. The young shoots have opposite leaves much broader than the older leaves, which are alternate. The calyx never opens. It is like a lid and falls off. Under this is another very thin lid which answers to the corolla. Then the numerous stamens rise and expand, producing a tassel-like blossom. The fruit is a 3–5-celled capsule imbedded in the receptacle and opening by chinks at the top. The commonest species in cultivation is the Blue Gum, *Eucalyptus globulus* Labill.

ONAGRA′CEÆ, Evening Primrose Family

Herbs with the calyx tube inserted on the ovary. Parts of the flower 4, except the stamens, which are generally 8. Capsule 4-celled, and stigma 4-lobed or capitate. Leaves simple, without stipules. Flowers usually showy.

I. ZAUSCHNE′RIA, Wild Fuchsia

Perennial herbs with many low ascending stems from woody rootstocks. Leaves opposite, except the upper ones. *Flowers large, scarlet, in racemes. Calyx with tube globose just above the ovary, the funnel-formed border 4-lobed, with 8 scales within, 4 erect and 4 deflexed.* Petals 4, obcordate and deeply cleft, a little longer than the calyx lobes. Stamens 8 in 2 sets, one shorter than the other. Anthers versatile. Stigma 4-lobed or shield-shaped. Pod 4-angled. *Seeds with a tuft of down at the end.*

Z. Califor′nica Presl. All the forms of *Zauschneria* are considered by many botanists to belong to this species. It is extremely variable, and found through California; blooming from summer until late in the fall.

II. EPILO′BIUM, Willow Herb

Perennial herbs often growing near water. *Calyx with tube short or none, border with 4 spreading, deciduous lobes.* Petals spreading or erect, purplish or white, often notched at the apex. Stamens 8 in 2 sets, one shorter; anthers versatile. Stigma with 4 spreading lobes or somewhat club-shaped. Pod 4-sided. *Seeds with a tuft of long white hairs.*

a. **E. spica′tum Lam.** Fireweed. Perennial, with tall, erect, simple, leafy stems. Leaves sessile, lance-shaped, entire. *Flowers reddish purple, large, in a long spike with noticeable bracts.* (The spike resembles a raceme because of the long, linear ovaries, which look like pedicels.) Style yellow, hairy at the base, with 4 linear stigma lobes. This is common in the Sierra Nevada Mountains wherever the timber has been burned, and also in the northern part of the Coast Mountains.

b. **E. panicula'tum Nutt.** *Annual, with slender stems branching widely above, low or 10 ft. high.* Leaves small, often in clusters on the main stem, almost wanting on the branches. Flowers small, rose-color, veined with darker lines, terminating the slender thread-like branches. Petals deeply notched, nearly twice as long as the calyx lobes. This is common, and blooms in the fall. Widely distributed.

c. **E. adenocau'lon Hausskn.** Stems ascending, tall, with the inflorescence branched. Leaves ovate-lanceolate, with rounded base, finely toothed margins, and short-winged petioles. Flowers small, rose-color, nodding at first. *Inflorescence and seed-pods glandular pubescent.* This is common and widely distributed. It grows near wet places. *Little rosettes of leaves appear late in the season at the base of the stem.*

III. ŒNOTHE'RA, Evening Primrose

Herbs with alternate leaves. *Flowers various, with calyx tube prolonged above the ovary, and the lobes reflexed,* often remaining somewhat united. Petals 4, white or yellow, turning reddish or, in some yellow-flowered species, greenish. Stamens 8, with anthers versatile. Stigma either with 4 linear divisions or capitate. The following are the most widely distributed species.

a. **Œ. Califor'nica Watson.** White Evening Primrose. Perennials, with low, rather stout stems covered with white, shining epidermis. *Flowers axillary, with petals white, obcordate, more than an inch long.* Style 4-cleft. Capsules 2 in. long, slightly tapering. Central and southern California.

b. **Œ. bien'nis L.** Yellow Evening Primrose. Stem erect, often 3 ft. high, leafy. *Flowers large (often more than 2 in. in diameter), yellow, in a leafy spike.* Stigmas with 4 linear lobes. This is generally found in moist places. There are several varieties, differing chiefly in the amount of pubescence and the size of the flowers. Widely distributed.

c. **Œ. gauræflo'ra T. & G.** Nodding Evening Primrose. Stems leafy, simple or branched from the base. *Flowers rather small (not ½ in. in diameter), very numerous, white, turning rose-color, in a nodding spike.* Capsules slender, linear, much contorted. This is common in the San Joaquin Valley on the sides of hills or gulches.

d. **Œ. ova'ta Nutt.** Sun Cups (incorrectly called Cowslips). *Low, with leaves and flowers from a fleshy root forming rosettes on the ground.* Leaves broadly lance-shaped, with the margins generally toothed or wavy, 3–8 in. long, often the midvein red. Calyx tube like a long stem, 1–4 in. long, extending down to the capsule, which is underground. *Corolla bright yellow, with petals ½ in. or more long.* Stigma capitate. This grows in moist places not far from the coast, and blooms early.

e. **Œ. campes′tris Greene.** *Annual, with many slender branches from the root, 6 in. to nearly a foot high.* Leaves narrow, linear, dentate. Calyx tube short, funnel-form, attached to the long linear capsule, which often becomes somewhat contorted. *Petals ½ in. or less long, bright yellow, sometimes spotted at base.* Anthers versatile, stigma capitate. This is generally many-flowered, and is quite common south of San Francisco.

f. **Œ. cheiranthifo′lia Hornemann.** *Stems decumbent, often 2 ft. or more long, white, with a close pubescence, especially on the younger parts.* Leaves oblanceolate to ovate, the upper sessile. Ovary and calyx woolly. *Petals yellow, generally turning greenish when withering.* Pods angled, becoming contorted. This is common on the sands along the coast, chiefly south of San Francisco, and is quite variable.

IV. GODE′TIA, "Farewell to Spring"

Calyx tube prolonged beyond the ovary, funnel-shaped, with reflexed lobes somewhat united, deciduous. *Petals 4, generally rose-color, often marked with spots of deeper color. Stamens 8 in 2 sets, one shorter than the other,* and ripening earlier; anthers attached at the base. Stigmas 4, generally purple. Capsule 4-celled. The following species are the most easily distinguished and most common.

a. **G. lep′ida Lindl.** Annual, erect herbs with white, shining stems. Flowers in spikes. *Tips of the calyx lobes free in the bud.* Petals rose-color, with a darker spot near the top. *Capsule with a single row of seeds in each cell, sessile, narrowed towards the apex, ribbed, white-hairy.* Monterey County to Oregon.

b. **G. amœ′na Lilja.** Stems loosely branching below, with widely spreading branches. Flowers nodding in the bud, large and showy (an inch or more in diameter). Petals white, rose-color, or purple, with a darker spot at the center. *Capsules narrowed at both ends, on short pedicels.* From Monterey County northward.

c. **G. quadrivul′nera Spach.** Stems slender, a foot or two high. Leaves narrow, entire or slightly denticulate, an inch or two long. *Tips of the calyx lobes slightly free in the bud.* Petals purplish, about half an inch long. Stigma lobes short, purplish. *Capsule narrowed to the top, ribbed and hairy. Seeds in one row in each cell.* This species is widely distributed.

d. **G. purpu′rea Watson.** Stems leafy, a foot or two high. Leaves oblong, entire, an inch or two long. Flowers in a leafy terminal spike. *Tips of the calyx lobes not at all free in the bud.* Petals deep purple, half an inch long. Stigma lobes purple, short. *Capsule ovate to linear-oblong, sessile, not ribbed. Seeds in 2 rows in each cell.* From Oregon to Los Angeles.

e. **G. Bot′tæ Spach.** Erect, with few branches, 1–2 ft. high, almost smooth. Leaves linear-lanceolate, 1–2 in. long, entire or with a few teeth on the margin. Petals light purple, about an inch long. *Pod narrowed at each end, about an inch long, on pedicels* $\frac{1}{2}$–$\frac{3}{4}$ *in. long.* This is common in southern California.

f. **G. epilobioi′des Wats.** Stems erect, slender, one foot or less high, slightly clothed with white down or smooth. Leaves linear. *Petals pale rose or white, a half inch or less long. Pod narrowed at each end,* an inch or less long. Common in southern California.

V. CLAR′KIA

Calyx tube prolonged beyond the ovary, funnel-shaped, with reflexed, united, deciduous lobes. *Petals 4, with long claws.* Stamens 8 in 2 sets, those opposite the petals often sterile. Anthers attached by the base. Pods linear.

The chief difference between *Clarkia* and *Godetia* consists in the clawed petals of the former.

a. **C. el′egans Dougl.** Stems simple or branched, from 6 in. to 6 ft. high. Divisions of the calyx united except on one side, deep wine-color on the inner surface. *Petals reddish purple, with long, slender claws and rhomboidal blades. Anthers all perfect.* Capsule nearly sessile, often woolly. Widely distributed.

b. **C. concin′na Greene (Eucharidium).** Stems slender, with spreading branches. Calyx tube very slender, an inch long. *Petals dark rose-color, 3-lobed. Stamens only 4.* Stigma lobes unequal. Capsules about an inch long, sessile. This is a very showy plant, blooming in summer. In the Coast Mountains.

c. **C. pulchel′la Pursh.** Stems branching, about a foot high. Leaves linear-lanceolate, 1–3 in. long, entire, smooth. *Petals rose-color, with 3 broad-spreading lobes, the claw with a pair of recurved teeth. Perfect stamens 4,* each with a scale on each side of the base. *There are 4 stamens that are rudimentary.* Stigma lobes dilated. Pod 1 in. long, 8-angled, on spreading pedicels. From northern California to British America.

LOASA′CEÆ. Blazing Star Family

Herbs covered with rough barbed hairs. Calyx tube attached to the 1-celled ovary with parietal placentæ. Stamens numerous, merging into the petals.

MENTZE′LIA, Blazing Star

Tall and erect, or loosely branching herbs, with stems white and shining. Flowers showy, yellow, orange or cream-color; from very small to 3 or 4 in. in diameter. The barbed hairs cause the plant to adhere to whatever it happens to touch. The numerous stamens and spreading petals give this plant a radiant appearance like a star. The species are local.

M. lævicau′lis T. & G. Biennial, with stout branching stems, 2–3 ft. high. Leaves lanceolate, 2–8 in. long. Flowers sessile on short branches, 3–4 in. broad, light yellow, blooming in the morning. Calyx tube naked. Petals 5–10. Stamens numerous. This is generally found growing in the beds of streams in the mountains through California to Washington.

CACTA′CEÆ. Cactus Family

Peculiar green fleshy perennial plants, armed with bundles of spines, and rarely possessing leaves. Flowers with numerous sepals, petals, and stamens, in several series, forming a cup above the 1-celled, many-ovuled ovary. Style 1, with several stigmas. Fruit a pulpy or, rarely, a dry 1-celled berry with numerous seeds. The following are the common genera.

I. MAMILLA′RIA, Bird's-nest Cactus

Round or oval plants, covered with spine-bearing tubercles. Flowers small, arising between the tubercles. *Ovary naked.* Seeds without endosperm.

II. ECHINOCAC′TUS, Indian Melon

Round or oval plants, usually ribbed, with bundles of spines on the ribs. Flowers from the youngest part of the ribs close above the growing bunches of spines. *Ovary covered with sepals.* Seeds with endosperm.

III. CE′REUS, Column Cactus

Oval or columnar plants, sometimes tall, ribbed, or angled, with bundles of spines on the ribs. Flowers larger than the two preceding, close above the bundles of full-grown spines. *Ovary covered with sepals.* Seeds without endosperm.

IV. OPUN′TIA, Jointed Cactus

Branching or jointed plants, with joints either flattened or cylindrical. Spines barbed, and accompanied by numerous short bristles that easily become detached. *Ovary bearing bristles in the axils of small terete deciduous sepals.* Seeds with the embryo coiled around the endosperm.

FICOI′DEÆ. Fig Marigold Family

Fleshy, succulent plants, with opposite leaves without stipules. Petals and stamens numerous, inserted on the tube of the calyx, which is adnate to the capsule.

MESEMBRYAN′THEMUM, Fig Marigold, Ice Plant

Calyx lobes 5, unequal. Petals numerous, linear. Stamens indefinitely numerous. Capsule with as many cells as styles (4–20), usually 5, dehiscent at the top.

M. æquilatera′le Haworth. Fig Marigold. Perennial, with stout, usually prostrate stems. Leaves thick, 3-sided, smooth, 1–3 in. long. Flowers crimson, nearly sessile. Fruit edible. This is common on the coast.

ARALIA′CEÆ. Ginseng Family

Perennial herbs or shrubs, generally with woody stems. Umbels not regularly compound. Styles and carpels more than 2. Fruit fleshy, forming a berry or drupe.

I. ARA′LIA, Ginseng, Spikenard

Calyx 5-toothed or entire. Petals 5, ovate. Stamens 5. Pistil with the ovary 2–5-celled, and the styles free or slightly united at base. Leaves alternate, compound. Umbels simple, either in racemes or panicles. *Pedicels not jointed.*

A. Califor′nica Watson. Herbs, 8–10 ft. high, from a thick aromatic root. Leaves large, bipinnate, with ovate-lanceolate leaflets, simply or doubly serrate. Umbels globular, generally in panicles. Fruit when ripe forming a purple berry. This is frequent along shaded streams.

II. FAT′SIA, Devil's Club

Densely prickly shrubs with large palmately lobed leaves and greenish white flowers in dense paniculate umbels. *Calyx teeth wanting.* Petals 5, valvate in bud. Stamens 5, alternate with the petals. Ovary 2–3-celled; styles 2. Fruit a drupe. *Pedicels jointed.*

F. hor′rida Benth. & Hook. Stems stout, woody, creeping at base, leafy at summit, very prickly. Leaves roundish, heart-shaped in outline, prickly on both sides. Styles united to the middle. This is common in shady woods from Oregon northwards. It forms thickets which, on account of the thorny stems, are almost impassable.

UMBELLIF′ERÆ. Parsley Family

Herbs with hollow, grooved stems and small flowers in umbels. Calyx usually a 5-toothed rim around the top of the ovary. Petals 5, small. Stamens 5, inserted on a disk on the top of the ovary. Ovary 2-celled and 2-ovuled, ripening into 2 carpel-like akenes, which readily separate from each other. Each carpel bears longitudinal ribs, in the furrows of which secondary ribs often occur. On a cross-section of the fruit the oil tubes are seen as dots. They traverse the spaces between the ribs, and are pretty near the surface of the fruit. The seeds contain a small embryo enclosed in considerable endosperm. The family is difficult, and the flowers are so much alike that the different genera and species are to be distinguished from each other chiefly by the characteristics of the fruit.

I. SANIC′ULA, Snakeroot, Sanicle

Leaves palmately lobed or pinnately divided. Umbels simple or imperfectly compound, with flowers sessile or on short pedicels. Bracts of the involucre leafy, toothed; those of the involucels small, entire. *Fruit covered with hooked prickles or tubercles.* Seeds round, with oil tubes more or less obscure.

a. **S. arctopoi′des H. & A.** YELLOW MATS, FOOTSTEPS OF SPRING. Stems prostrate, branching from the base. Leaves deeply 3-lobed, with the divisions raggedly cleft. Fruit on short pedicels. *This is very conspicuous in early spring, dotting the ground with its small mat of yellowish green flowers and leaves, during the rainy season.* It is generally in bloom early in January. Throughout California.

b. **S. bipinnatif′ida Dougl.** PURPLE SANICLE, NIGGER-BABIES. Erect, with lower leaves opposite, upper alternate, pinnately 3–5-parted, with the divisions toothed or lobed (generally the teeth are tipped with bristles). *Flowers purplish, in umbels with 3 or 4 elongated rays.* Throughout California.

c. **S. tubero′sa Torr.** *Stems low from a small tuberous root.* Leaves finely dissected. Involucre with 1–4 rays, leafy; involucels small, unequally lobed. Heads small. Flowers yellow. *Fruit covered with tubercles instead of prickles.* Widely distributed, often growing on stony hills. There is a disagreeable odor about the plant.

II. HERACLE′UM, Cow Parsnip

This is a stout, tall herb with large thrice-compound leaves. *Leaflets broad, deeply and irregularly toothed.* Umbels large, compound, with many-leaved involucels. Calyx teeth small or none. *Petals white, conspicuous, the outer ones 2-cleft and larger than the inner.* Fruit tipped with a thick conical enlargement of the style, with 3 blunt ribs on the outside of each carpel, and a large oil tube in each interval between the ribs. Seeds flat.

H. lana′tum Michx. This is the only species. The stem is generally woolly. It grows everywhere not far from water.

III. DAU'CUS, Carrot, Rattlesnake Weed

Calyx 5-toothed, fruit oblong, with the primary ribs bristly, and the secondary ones winged with a row of barbed prickles more or less united. Oil tubes under the wings. Leaves much dissected with very small segments. Involucres like the leaves, but smaller. *Outer rays of the umbel longest and folding over the others in fruit.* Flowers greenish.

D. pusil'lus Michx. YERBA DE LA VIBORA, RATTLESNAKE WEED. Annual, erect, simple or branched, with the umbels terminating the stems. The fruit tastes something like lemon peel. This is the most widely accepted antidote for the bite of the rattlesnake. Widely distributed.

CORNA'CEÆ. DOGWOOD FAMILY

Generally trees or shrubs, with opposite simple and entire leaves without stipules. Flowers in heads or cymes. Sepals, petals, and stamens 4. Calyx adnate to the 1 or 2 celled ovary, which becomes a 1 or 2 seeded drupe or berry in fruit. The seeds have hard endosperm and a minute embryo.

COR'NUS, Dogwood

Calyx minutely 4-toothed. Petals white or yellowish green.

a. **C. Nuttal'lii Audubon.** LARGE-FLOWERED DOGWOOD. This is usually a small tree with smooth bark. *Flowers numerous in a head surrounded by a conspicuous involucre of large white or yellowish bracts often tinged with red and resembling petals. Berries bright red in clusters.* This grows along streams, chiefly in the northern part of California.

b. **C. pubes'cens var. Califor'nica C. & R.** COMMON DOGWOOD. Shrubby, with smooth, reddish branches. Leaves ovate to oval, acute at base, acute or pointed at top. Flowers white in cymes, flowering almost throughout the year. Fruit dull white, rounded, with stone somewhat flattened, ridged on the sides and furrowed on the edge. This is common throughout the state, growing along streams.

c. **C. stolonif'era Michx.** *Shrub 3–9 ft. high,* bearing stolons. Stems bright red-purple and smooth. Leaves lanceolate to oblong, pointed at top, obtuse at base, white on the lower surface from the close pubescence. Flowers in small cymes. Calyx teeth minute, petals white, fruit white or lead-color. Oregon to British Columbia.

GARRYA'CEÆ. Silk-tassel Bush Family

GAR'RYA, Silk-tassel Bush, Quinine Bush

Evergreen shrubs with opposite leathery leaves. Flowers grayish green, apetalous, diœcious, in pendent axillary catkins, which are solitary or several. Sterile flowers with 4-parted calyx, and 4 conspicuous stamens on distinct filaments. Fertile flowers with a 2-lobed calyx or none, styles 2, ovary 1-celled, containing 2 ovules. Fruit a berry with a brittle outer covering, pulpy within, and containing 1 or 2 seeds. This is the only genus.

a. **G. Fremon'tii Torr.** Leaves becoming glabrous, not wavy-margined. Fruit very bitter, purple. Sterile catkins 2–3 in. long. Middle California.

b. **G. ellip'tica Dougl.** Leaves white-woolly on the lower surface, wavy-margined. Fruit, when ripe, red-purple, pleasantly acid, with a hint of bitterness. The sterile catkins are from 2 to 5 in. long, and look like fringe. From Monterey County to Oregon and Washington.

ERICA'CEÆ. Heather Family

Herbs or woody plants. Leaves simple, evergreen or deciduous, without stipules. Stamens as many or twice as many as the parts of the corolla; anthers 2-celled, opening by little holes at the top. Ovary generally with as many cells as there are parts to the corolla, inferior in *Vaccinium* but superior in the other genera. Style simple. Fruit a berry or a pod with axillary placentæ.

I. VACCIN'IUM, Huckleberry

Shrubby. Calyx and corolla apparently on the summit of the ovary, the calyx tube being adnate to the ovary. Stamens

8–10, with separate cells to the anthers, which taper upwards. *Fruit a berry crowned with the 5-toothed calyx.*

a. **V. ova′tum Pursh.** Leaves evergreen, glossy, serrate, acute. Flowers crowded in short clusters in the axils of the leaves and at the ends of the branches. Corolla bell-shaped, pink. Stamens 10. *Berries dark blue or purple, edible.* This is common in the Coast Mountains from Monterey County to Oregon.

b. **V. parvifo′lium Smith.** Stems much branched, with the branches sharply angled. Leaves deciduous, oblong, entire, dull green above, pale beneath. Corolla globular. Stamens 10. Anthers with long tail-like appendages on the back. *Berries pale red, edible.* Northern California to Alaska.

II. AR′BUTUS, Madroño, Madrone

Trees with thick, evergreen, alternate leaves. Flowers white, in terminal panicles. Calyx small, 5-lobed. Corolla urn-shaped, with 5 recurved teeth, and large honey-glands near the base. Stamens 10 ; anthers flattened, with a pair of horns on the back below the summit. Ovary raised on a disk, 5-celled. *Fruit, when ripe, a round red berry with a rough, tubercled surface, edible but rather dry.*

A. Menzie′sii Pursh. This is a beautiful tree or sometimes a shrub, with smooth, brownish red bark, which peels off in the summer. The leaves are large, oblong, serrate, bright green above, pale beneath. The tree is beautiful at all times; when in bloom fragrant and adorned with large panicles of flowers like lilies of the valley; in autumn gorgeous with the large clusters of fruit, varying in color from greenish yellow to bright scarlet, as large as green peas. In the Coast Mountains and Sierra foothills to Puget Sound.

III. ARCTOSTAPH′YLOS, Kinnikinick, Manzanita

Shrubs with alternate, evergreen leaves and smooth bark that peels off in summer. Flowers white or pink, variously clustered. Calyx small, 5-lobed. Corolla urn-shaped, with 5 recurved teeth and large honey-glands near the base. *Stamens 10, anthers flattened, with a pair of horns on the back at the summit.* Ovary raised on a disk, 5-celled. Fruit a berry, containing stony seeds that are separable or cohere into one.

a. **A. Manzani′ta Parry.** COMMON MANZANITA. Erect and branching, becoming tree-like, with smooth, polished dark-red stems and branches. The young shoots and the leaves are ashy gray, becoming smooth with age. The leaves are generally vertical by a twist in the petiole. Flowers crowded in short racemes on smooth pedicels with short, pointed bracts. Fruit smooth, about the size of a pea. This sometimes becomes a tree. In valleys of the Coast Mountains.

b. **A. Stanfordia′na Parry.** A delicately branched shrub, either erect or spreading, with slender peduncles and pedicels, small scale-like bracts and dark-green, smooth leaves, round and small. *The flowers are smaller than in other species, and are deep rose-color, rarely white.* The berries are smooth, rather small, and the seeds coalesce more or less. This is common in the northern Coast Mountains, and is perhaps the most beautiful species.

c. **A. tomento′sa Dougl.** *Shrub with hairy stems* and leaves more or less clothed with a close pubescence. *Flowers in short panicles with leafy bracts which are most conspicuous in the buds.* Flowers white, rather large. Berries with the seeds coalescing more or less. This is one of the most widely distributed species, and embraces a great many forms chiefly distinguished by the amount of pubescence. It is never destroyed by brush fires, and the old roots become chunks of solid wood.

d. **A. canes′cens Eastwood.** This is somewhat similar to the preceding, but *the entire plant is white-downy.* The flowers are more often pink than white, and the habit of the plant is more spreading. The bracts are large and leaf-like. This is widely distributed in northern California.

e. **A. Anderso′nii Gray.** This is similar to **A. tomento′sa.** The leaves are thin, bright green, smooth or slightly pubescent, with *the base arrow-shaped or heart-shaped,* either sessile or short-petioled. It is found in the Coast Mountains of California, in San Mateo, Santa Cruz, and Alameda Counties.

f. **A. vis′cida Parry.** Shrub 3–5 ft. high, with smooth, pale-gray or glaucous leaves. Panicles erect in bud, becoming pendent later. Flowers pink or white, rather small, on slender, *very viscid pedicels.* Fruit a berry containing seeds that coalesce more or less. The bracts are small and scale-like. This species is very abundant in the foothills of the Sierra Nevada and in the hills of Lake and Mendocino Counties.

g. **A. glau′ca Lindl.** BIG-BERRIED MANZANITA. The foliage of this is always glaucous and smooth. It is distinguished from all other species by the large berries, often $\frac{3}{4}$ in. in diameter, with *the stones consolidated into a thick, solid mass.* Most common southward.

h. **A. bi′color Gray.** Shrub 3 or 4 ft. high. Leaves oblong to oval, 1–2 in. long, leathery, clothed with white down on the lower surface, green and glabrous on the upper. Corolla rose-color, small. *Fruit a smooth berry with a solid seed.* Southern California, especially in San Diego County.

i. **A. U′va-Ur′si.** KINNIKINICK. Stems forming a mat on the ground. Leaves small, very glossy. Flowers in short, simple racemes. *Fruit bright red and smooth when ripe.* Northern California to British Columbia.

There are many other species more local and difficult to distinguish.

IV. GAULTHE′RIA, Salal

Stems shrubby but slender, ascending or spreading, creeping under ground. Leaves alternate, broad, evergreen, glossy. Flowers nodding, solitary or in racemes, in the axils of the leaves. *Calyx 5-cleft, becoming fleshy in fruit and enclosing the capsule.* Corolla 5-toothed. *Stamens 10 within the corolla, the anthers tipped with bristles.* Ovary 5-celled, with many ovules, in fruit forming a sweet aromatic berry which is edible.

G. Shal′lon Pursh. SALAL. Stems sometimes 3–4 ft. high, almost climbing among trees and bushes. Racemes glandular. Corolla pink, urn-shaped. *Fruit black when ripe, with dark-purple pulp.* From Santa Barbara to British Columbia.

V. RHODODEN′DRON, Azalea

Calyx very small. *Corolla large, funnel-form, 5-lobed. Stamens 5–10, with long, slender filaments reclining along the lower side of the flower.* Capsule woody, dehiscent from the summit, at the partitions, by 5 valves. Flowers showy, in umbels, the bracts falling as the flower opens.

a. **R. Califor′nicum Hook.** ROSE BAY. *Shrub with smooth evergreen leaves. Flowers rose-color, numerous, in a terminal umbel.* Upper lobes of the corolla yellowish and spotted within. This is a beautiful shrub of northern California, Oregon and Washington, often growing in patches covering acres. It is the State Flower of Washington.

b. **R. occidenta'le Gray.** AZALEA. *Shrub with bright-green deciduous leaves. Flowers large, fragrant, appearing after the leaves, in numerous umbels.* Corolla viscid, white or rose-color, the upper lobes blotched with yellow within. Stamens and styles very long. This is found along streams in both the Coast and Sierra Nevada Mountains.

VI. LE'DUM, Labrador Tea

Shrub *with alternate, evergreen leaves more or less covered with resinous dots.* Flowers white, in corymbs or umbels. Calyx 5-lobed, small. Corolla of 5 obovate, widely spreading petals. Stamens 5–10, as long as the petals. *Pod 5-celled, with 5 valves opening from the base upwards.*

a. **L. glandulo'sum Nutt.** *Leaves smooth on both sides, but paler and more glandular beneath.* Flower clusters often crowded, terminal or axillary. This is common at high elevations in the Sierra Nevada and on the coast from northern California to British Columbia.

b. **L. latifo'lium Ait.** *Leaves densely white-woolly beneath, becoming brownish, margins with the edges turned back,* oblong, obtuse, 1–2 in. long, ½ in. wide. Flower clusters all terminal. Northern California to British Columbia.

VII. CHIMAPH'ILA, Prince's Pine

Herbs with low stems from slender rootstocks. Leaves evergreen, alternate or sometimes opposite, toothed. Flowers few, fragrant, waxy-looking, in terminal corymbs. Petals 5, widely spreading, regular, orbicular, concave. Stamens 10, on short filaments which are dilated and hairy in the middle. *Stigma round-shield-shaped, concealing the short style, 5-rayed. Pod splitting from the top downwards, not woolly on the edges of the valves.*

a. **C. umbella'ta Nutt.** Stems about 6 in. to a foot high, with the leaves often in whorls, not spotted. Peduncle 4–7-flowered, with the bracts narrow and deciduous; *filaments hairy on the margins only.* California to British Columbia.

b. **C. Menzie'sii Spreng.** Stems about 6 in. high, with a few branches from the base. Leaves sometimes mottled with white. Peduncles 1–3-flowered. *Filaments slender, with a woolly dilated central part.* California to British Columbia.

VIII. PYR′OLA, Wintergreen

Herbs with radical leaves and *flowers nodding in racemes, on scapes.* Calyx 5-lobed. Corolla with 5 incurved petals. Stamens 10, usually declined. *Anthers erect in bud, 2-horned at base, but becoming inverted when the flowers expand.* Style declined or straight. Fruit a capsule opening down the middle of the cell walls on the back.

a. **P. rotundifo′lia L.** Leaves round, shining or dull, on long petioles. Scapes from 6 in. to a foot high. Flowers white, pink or rose-color, almost ½ in. in diameter. Anthers narrowed at top. Style declined, with a collar at base of the stigma. In wet places in the mountains, widely distributed.

b. **P. pic′ta Smith.** *Leaves orbicular, thick, veined or blotched with white, often purplish beneath.* Scapes about 6 in. high, 7–15-flowered. Petals greenish white, longer than the sepals. Northern California to Alaska.

c. **P. aphyl′la Smith.** *Leafless or with a few small, poorly formed leaves.* Scapes reddish, 6 in. high. Flowers similar to the above, rose-color. In deep woods from California to Washington.

PRIMULA′CEÆ. Primrose Family

Herbs with perfect, regular flowers, parts of the calyx and corolla 5 (sometimes 4, 6, or 8). Stamens equaling the lobes of the corolla and opposite them, inserted on the tube of the corolla. Pistil with a single style and stigma, the ovary 1-celled, with a globular central placenta.

I. DODECA′THEON, Twelve Gods, Shooting Stars, Prairie Pointers, Cyclamen

Herbs with leaves clustered at the base of the scape. Flowers showy, in simple, terminal umbels. *Calyx 5-cleft, with the divisions reflexed in flower, erect in fruit. Corolla with an extremely short tube, an open throat, and 5 reflexed narrow divisions, which are white, rose-color or purple. Stamens inserted on the throat of the corolla, with short monadelphous filaments, and long yellow or violet anthers conniving around the long style and forming the point of the flower.*

a. **D. Henderso′ni Gray**. *Roots becoming small tubers and each forming a new plant.* Leaves ovate or obovate, smooth, on broad petioles. Scape 6–12 in. high. Divisions of corolla 4 or 5, rose-purple; tube darker, with a ring of yellow. Anthers erect. Pod twice as long as the calyx, opening by a lid below the summit. This is the commonest species in early spring on hillsides of the Coast Mountains, and extends from middle California to Oregon.

b. **D. Clevelan′di Greene.** *Roots somewhat fleshy, but not forming tubers. Stems and leaves pale green and glandular.* Leaves ascending, spatulate or obovate. Divisions of corolla bright purple, yellow at base; tube dark purple with yellow lines. Pods opening by a lid at top. Southern California.

There are several other species, chiefly growing in the higher mountains.

II. TRIENTA′LIS, Star-flower

Low perennial herbs from tuber-bearing, slender rootstocks. *Stems simple, with the leaves in a whorl below the flowers. Flowers small, star-shaped, on slender pedicels.* Calyx and corolla 7-parted (sometimes 6–9-parted), with divisions widely spreading. Stamens with slender filaments united into a ring at the base. Capsule splitting into five parts, with few seeds.

T. Europæ′a var. latifo′lia Torr. This grows in the woods and blooms in the spring. The petals are white or rose-color.

III. STEIRONE′MA

Stems erect, leafy. Leaves entire, opposite or whorled. Flowers yellow, axillary, nodding on slender pedicels. Corolla wheel-shaped, apparently with petals distinct, each division wrapped around its stamen in the bud. *Filaments united around the base of the corolla in a ring, every alternate one being sterile.* Capsule many-seeded.

S. cilia′tum Raf. Stem simple. Leaves ovate-lanceolate, 2–4 in. long, rounded or somewhat *heart-shaped at base*, with long ciliate petioles. In moist thickets. Washington. Summer.

IV. ANAGAL′LIS, Pim′pernel, Poor Man's Barometer

Spreading or prostrate annuals, with stem leaves opposite or whorled. Flowers on axillary peduncles, salmon-color, with a darker spot in the center (rarely blue or white); *calyx and corolla wheel-shaped. Filaments bearded.* Capsule globose, the top falling off as a lid.

A. arven′sis L. This is common everywhere, and has been introduced from Europe.

PLUMBAGINA′CEÆ, Sea Pink Family

Ours are maritime herbs, with all parts of the flower 5, except the 1-celled, 1-ovuled ovary. Leaves alternate, entire, clasping the stem. Calyx tubular or funnel-form, 5-toothed. Corolla with 5 petals, united at base into a ring. Stamens 5, opposite the petals, and inserted at their base. Ovary 5-angled at summit, with 1 ovule; styles 5.

I. ARME′RIA, Thrift

Stemless perennials, with narrow, linear, persistent leaves in close tufts. Flowers in a head subtended by an involucre, on a long scape. Corolla 5-parted, of 5 distinct petals.

A. vulga′ris Willd. Sea Pink. Corolla rose-color. This is common along the coast, blooming in spring.

II. STAT′ICE, Sea Lavender

Flowers in small one-sided spikes crowded at the ends of the numerous widely spreading branches. Leaves with a broad, tough blade tapering to a petiole.

S. Limo′nium L. var. Califor′nica Watson. Sea Lavender. Corolla violet. This is common in salt marshes, blooming in summer.

OLEA′CEÆ. Ash Family

Trees or shrubs having opposite leaves without stipules. Corolla 2 or 4 lobed. Stamens 2. Ovary 2-celled, with 2 ovules hanging from the top of each cell. Fruit often 1-celled and 1-seeded, either a stone fruit, as the olive ; a pod, as the lilac ; or a winged fruit, as the ash.

FRAX′INUS, Ash

Trees or shrubs with compound leaves and diœcious or polygamous flowers. Calyx small, 4-cleft. Petals 2 or none. Stamens 2, with large anthers. Fruit winged from the top.

a. **F. dipet′ala Hook. & Arn.** Flowering Ash. A small tree or shrub with 5–7 separate leaflets on petioles. Flowers showy, in panicles. Calyx 4-toothed. *Petals 2, white, as long as the anthers.* This grows along streams in the Coast Mountains.

b. **F. Orega′na Nutt.** Oregon Ash. A large tree with dark-colored bark. Leaflets 5–7, entire, sessile, usually tomentose when young, becoming smooth with age. *Flowers without petals.* From Fresno County, in the mountains, to Oregon and Washington.

GENTIANA′CEÆ. Gentian Family

Glabrous herbs with entire opposite leaves without stipules. Stamens as many as the lobes of the corolla, inserted on its tube, and alternating with the lobes. Stigmas 2, sessile or on one style. Ovary 1-celled. Fruit with 2 parietal placentæ dehiscent at the partitions. Seeds with abundant endosperm around the minute embryo.

ERYTHRÆ′A, Canchalagua

Low, much-branched herbs, with numerous showy flowers in cymes. Corolla rose-color, salver-form, with lobes convolute in the bud. Anthers twisting spirally after the pollen is shed. Stigmas at first united, wedge-shaped or fan-shaped, afterwards spreading.

E. venus′ta Gray. Corolla deep pink, with yellow center; divisions half as long as the tube. This is the handsomest and most widely distributed species.

(True gentians are rare in California, and are mostly confined to the high mountains.)

ASCLEPIADA′CEÆ. MILKWEED FAMILY

Herbs with a milky juice and a tough inner bark having a fiber like flax. Leaves opposite, entire. Flowers peculiar in shape, in umbels. Sepals and petals each 5, reflexed. Anthers forming a crown united to the solid stigma, and with peculiar hood-like appendages surrounding it. The anther cells are orange in color, and are concealed in the crown, and have the outline of a pair of scales. Fruit a pod, opening at one side. Seeds arranged symmetrically on a thick axis, each provided with a tuft of silky down.

I. ASCLE′PIAS, Silkweed, Milkweed

The five hoods of the stamens are each provided with a protruding horn.

a. **A. specio′sa Torr.** Covered with white down. Stems stout, erect, with large, thick, oblong leaves, opposite or whorled. Umbels on peduncles shorter than the leaves, many-flowered. Flowers large, purple; the hoods nearly half an inch long, spreading, *with a horn-like prolongation from the summit; besides the short, inflexed true horn. Follicles rough with soft spinous processes.* California to Washington. This is inclined to become a troublesome weed.

b. **A. Mexica′na Cav.** Stems rather slender, 3–6 ft. high. Leaves in whorls of 3–6, linear, sessile, smooth, 3–6 in. long. Umbels clustered to form a corymb, densely flowered on peduncles longer than the petioles. Flowers rather small, greenish white or tinged with purple. *Hoods broadly ovate, shorter than the beak-like, incurved horn.* Follicles slender, tapering to the top. California to Oregon, spreading as if introduced, along highways.

II. GOMPHOCAR′PUS

The five hoods are without horns.

G. cordifo′lius Benth. Smooth, with ascending stems, 2–3 ft. high. Leaves ovate, clasping by a heart-shaped base, opposite or sometimes in threes. Umbels 1–4, with the flowers loose, on thread-like pedicels. Corolla dark red-purple. Horns tipped with a point where the open edges come together. Follicles smooth, inclined to be erect, on deflexed pedicels. This is common in California, blooming in late summer, and growing in dry ground in the valleys and foothills.

APOCYNA′CEÆ. Dogbane Family

Perennial herbs with milky juice and opposite entire leaves without stipules. Flowers in cymes or corymbs, regular, all the parts 5, except the pistil, which consists of 2 ovaries, with the styles and stigmas united. Fruit a pair of slender follicles. Seeds with a tuft of silky down.

APOC′YNUM, Indian Hemp, Dogbane

Corolla bell-shaped, 5-cleft, with 5 scales opposite the lobes and near their base. Stamens inserted on the base of the corolla, with short filaments and arrow-shaped anthers, uniting into a ring.

a. **A. androsæmifo′lium L.** *Corolla rose-color*, with revolute lobes and a bell-shaped tube longer than the calyx. This is generally much branched, and the flowers are numerous in loose cymes. Widely distributed.

b. **A. cannab′inum L.** *Corolla white*, with erect lobes, and the tube not longer than the calyx. Flowers small, in dense cymes. This grows in marshy places. Widely distributed.

POLEMONIA′CEÆ. Phlox Family

Herbs or rarely shrubs. Leaves simple or divided, without stipules. All parts of the flower 5, except the pistil, which has a 3-lobed style and a 3-celled ovary with axillary placenta. Stamens on the tube of the corolla, alternate with its lobes. Embryo with endosperm.

GIL′IA

Herbs or rarely shrubs. Leaves various, alternate or opposite. Calyx partly herbaceous, generally papery below the folds, with lobes narrow and acute. Corolla from funnel-form and salver-shaped to bell-shaped and wheel-shaped. The seeds generally become mucilaginous when wet. The flowers are showy, and among our most characteristic spring annuals; the species are numerous, and are not always easily distinguished. Only the most distinct and common are given.

a. **G. grandiflo′ra Dougl.** SALMON-COLOR GILIA **(Collo′mia).** Flowers crowded at the summit of an erect stem; *corolla pale salmon-color*, with the tube nearly an inch long and the border almost as broad. Widely distributed.

b. **G. squarro′sa Esch.** SKUNKWEED **(Navarre′tia).** Stems low, branching diffusely, viscid. Leaves and bracts pinnately parted, with spiny divisions. *Flowers small, deep blue.* This blooms late in the summer. *The whole plant has the odor of the skunk.* Widely distributed.

c. **G. tri′color Benth.** BIRD'S EYES. Stems slender, branching. *Corolla ½ in. long, with a yellow tube, the funnel-form throat marked with deep violet-purple, and the limb white or lilac.* It is sweet-scented and very pretty. Throughout western California.

d. **G. dicho′toma Benth.** EVENING SNOW **(Linan′thus).** Erect and branching herbs with very slender stems. The leaves are few, small, and far apart. *Flowers large, terminating the peduncles, salver-form, with the divisions convolute in the bud, showing only the dull-pink outer edges, opening about 4 o'clock.* Where they are abundant they look like snow on the ground. The white flowers are often more than an inch in diameter, and have a sweet, heavy perfume. Throughout western California.

e. **G. androsa′ceus Benth. (Linan′thus).** Stems leafy, with palmately parted leaves, apparently whorled, with thread-like divisions. Flowers crowded in a terminal cluster. *Corolla salver-form, with a long, slender tube, rose-color, lilac or white.* This is a handsome and widely distributed species, but variable and difficult to distinguish from allied species.

f. **G. micran′tha Steud.** Smaller in all its parts than the preceding, with the tube of the corolla long and thread-like, 1–1½ in. long. Flowers small, rose-color, white, or lilac. Common through California.

g. **G. cilia′ta Benth.** Stems slender, erect, clothed with white hairs. Flowers and bracts in a dense, capitate cluster, very hispid and ciliate. Corolla small, pink or white, extending beyond the bracts but little. This is widely distributed through California, and common.

h. **G. dianthoi′des Endl.** FRINGED GILIA. Stems from an inch to less than a foot high, simple or branching from the base. Leaves thread-like. *Corolla pink, with yellowish throat and very short tube.*

The corolla lobes are fringe-toothed. This is common in southern California, and is one of the prettiest spring annuals.

i. **G. Califor′nica Benth.** *Shrubby, 2 or 3 ft. high, with rigid branches.* Leaves *with spiny divisions*, widely spreading, clustered. Corolla *rose-color, fading to lilac, salver-form*, with the border an inch or more in diameter, the lobes often shortly fringed on the margin. This is common in southern California, chiefly on dry hills. It is very showy, with its numerous flowers, like those of phlox, in dense clusters terminating the branches.

j. **G. aggrega′ta Spreng.** SCARLET GILIA, WILD CYPRESS. Stems erect, simple or branched, viscid. Leaves compound, with narrow, linear leaflets. Flowers in a close panicle. *Corolla salver-form, nearly 1 in. long, scarlet, pink or white*, extremely variable in color. This grows in the mountains or near streams on the plains. Summer.

CONVOLVULA′CEÆ. MORNING-GLORY FAMILY

Twining or trailing herbs, with alternate leaves, and flowers solitary or few, on peduncles in the axils of the leaves. Calyx of distinct sepals. Stamens alternating with the parts of the corolla. Ovary 2 or 3 celled, with a pair of ovules in each cell. Capsule globular, containing 1–4 seeds.

I. CONVOL′VULUS, Morning-glory

Corolla open funnel-form, with the border 5-angled. Stamens inserted within the tube. Style slender. Stigmas 2. Capsule 2-celled and generally 4-seeded, with dehiscent septifragal dehiscence (the valves separate from the partition). Cotyledons folded and crumpled in the seed with some endosperm.

a. **C. Soldanel′la L.** SEASIDE MORNING-GLORY. *Low and trailing herbs, with stem and leaves fleshy. Leaves kidney-shaped, on long petioles.* Bracts of the peduncle close to the calyx, thin in texture. Corolla pink or purple, an inch or more in length. Pod becoming 1-celled. This grows on sandy beaches.

b. **C. villo′sus Gray.** Stems trailing. *Leaves hastate.* Bracts narrow, close under the calyx. *Corolla cream-color*, an inch long. *The entire plant is covered with a close, soft, velvety, white down.* Throughout California, but not very common.

c. **C. lute'olus Gray.** Stems often twining over high bushes, smooth, blooming at all seasons. *Peduncles as long as the leaves, with a pair of linear or lanceolate bracts a little below the flower* (no bracts directly under the calyx). Corolla pale cream-color, or (when growing near the coast) light or deep rose-color. Throughout California.

II. CUS'CUTA, Dodder, Love Vine

Parasitic plants with yellow or orange stems, scales in place of leaves, and densely clustered small white flowers. Calyx 5-cleft or parted. Corolla bell-shaped or tubular. Stamens inserted on the throat of the corolla, with fringed scales below. Ovary 2-celled, containing 4 ovules. Styles 2, distinct. Embryo without cotyledons, thread-like, spirally coiled in hard endosperm. The seeds germinate in the soil, but do not form roots there. Instead, they attach themselves to the other plants by means of little roots, and take all their nourishment from their hosts.

a. **C. sali'na Engelm.** SALT-MARSH DODDER. *Corolla having a shallow bell-shaped tube.* Capsule pointed. This grows in salt marshes on plants belonging to the *Chenopodiaceæ.*

b. **C. subinclu'sa Durand & Hilgard.** *Corolla with a rather long, urn-shaped tube.* Capsule conical. This grows on shrubs or coarse herbs.

HYDROPHYLLA'CEÆ. BABY-EYES FAMILY

Herbs, or rarely shrubs, with alternate leaves without stipules (rarely opposite). Flowers in coiled spikes or racemes, usually showy. Calyx 5-parted, or of 5 separate sepals. Corolla 5-lobed. Stamens on the corolla tube, and alternate with its lobes and shorter. Styles 2 or 2-cleft. Capsule 1 or 2 celled, with 2 parietal placentæ, splitting along the back of each valve.

I. HYDROPHYL'LUM, Waterleaf

Herbs from fleshy, running rootstocks. Leaves large, alternate, pinnately compound. Flowers white or blue, in close or open cymes, on long peduncles. Corolla bell-shaped, with a honey-gland at the base of each lobe. Stamens and style longer than the corolla. *Filaments bearded at the middle.* Styles 2-cleft. *Ovary 1-celled.*

a. **H. occidenta'le Gray.** Stems perennial, 1–2 ft. high, hairy. Leaves broad, pinnately divided; divisions 7–15, oblong, 1–2 in. long, the apex cut into long, uneven teeth, obtuse. Cymes on long peduncles, densely flowered. Calyx with erect, narrow, lanceolate, obtuse divisions. Corolla pale violet or white. California to Washington.

b. **H. capita'tum Dougl.** Bear's Cabbage. Low, from many fleshy roots. Leaves pinnately 5–7-parted or divided, with the divisions 2–3-lobed or cleft into oblong, mucronate lobes, soft-hairy, broadly ovate in outline, 2–3 in. long. Flowers densely clustered in close cymes like heads, on peduncles shorter than the petioles. Calyx clothed with stiff hairs. Corolla dull white or violet. From California, in the mountains at rather high elevations, to Washington. It comes up and blooms very soon after the snow melts.

II. NEMO'PHILA

Annual herbs, flowering very early, with the leaves pinnately lobed or divided, the lowest leaves opposite. Flowers solitary, on long peduncles in the axils of the leaves. Calyx 5-parted, with a reflexed lobe at each sinus, enlarging and covering the fruit. Corolla generally saucer-shaped, the throat within having 10 scales. Style 2-cleft. Capsule 1-celled.

a. **N. auri'ta Lindl.** Climbing Nemophila. Stems succulent, long and weak, clinging for support to other plants by means of stiff reflexed bristles. *Leaves deeply cut into 5–9 lobes, curved downwards, dilated at base, and auriculate.* Corolla violet, the throat purplish. Southward from San Francisco.

b. **N. macula'ta Benth.** Low annuals, growing in the higher Sierras. *Corolla white, with a violet spot on each lobe.*

c. **N. insig'nis Dougl.** Baby-blue-eyes. Low, spreading, growing in sandy places. *Corolla clear blue, nearly an inch in diameter.* This is the commonest species.

d. **N. atoma'ria Fisch. & Meyer.** Low, spreading, growing in wet places. *Corolla white, dotted with dark purple.*

e. **N. interme'dia Bioletti.** Taller than the last two, growing amid the brush. *Corolla light blue, with lines and dots radiating to the center.*

III. ELLIS'IA

Leaves once or twice divided. Flowers small and white. *Calyx without the reflexed lobes.* Corolla generally shorter, or but little longer than the calyx, which enlarges under the fruit. Style 2-cleft. Capsule 1-celled.

a. **E. membrana′cea Benth.** *Stems succulent, light-green, smooth except for some stiff bristly hairs that sometimes help support the weak stems.* Leaves pinnately divided into 3–9 obtuse, linear divisions with margined petioles. This generally grows in shady and damp places. From middle California to San Diego.

b. **E. chrysanthemifo′lia Benth.** Stems much branched. Leaves 2 or 3 times divided into small and short divisions. *Flowers in loose racemes on short, slender pedicels.* From middle California to San Diego.

IV. PHACE′LIA

Herbs with simple or compound leaves, and flowers in loosely or closely coiled spikes or racemes. *Calyx deeply 5-parted, without reflexed lobes.* Corolla readily falling, blue, white, or purple (rarely rose-color), from wheel-shaped to funnel-form, with vertical scales attached between the bases of the filaments, sometimes attached to the filaments. *Pistil with 2-cleft style and 2-celled ovary.* Seeds 4 to many.

a. **P. circina′ta Jacq.** Perennial from a stout root, a foot or two high. *Leaves grayish green, hairy, simple, or the lowest compound with 1 or 2 pairs of leaflets.* Spikes crowded, conspicuously coiled. Corolla small, whitish or lilac. Stamens conspicuous. This is found in many forms and is widely distributed.

b. **P. divarica′ta Gray.** Annual, low, with spreading branches inclined to be prostrate. *Leaves oblong on petioles shorter than the blades, simple or with 1 or 2 teeth or lobes at the base.* Flowers in loose racemes, corolla bluish purple, $\frac{3}{4}$ in. in diameter.

c. **P. Menzie′sii Torr.** Stems 6–10 in. high, branching above, gray with a close pubescence and rough with stiff hairs. *Leaves linear, entire or cleft into linear lobes.* Flowers in spikes or spike-like racemes which are clustered to form close panicles. Corolla violet or white, half inch or more in diameter, with long, narrow appendages at base, free from the filaments. Pod shorter than the calyx, with several seeds. From California, in the Sierra Nevada to British Columbia.

The species are numerous, and many are local; nearly all are beautiful, with conspicuous flowers.

V. EMMENAN′THE, Whispering Bells

This chiefly differs from *Phacelia* in the corolla, which is *bell-shaped, withering-persistent, and becoming papery,* yellow or yellowish white, sometimes tinged with pink.

E. penduliflo′ra Benth. Annual, simple up to the inflorescence or branched diffusely from the base, from a few inches to a foot high. The leaves are divided into numerous short, toothed or sharply cut lobes. The racemes are panicled, with the bell-shaped flowers on slender pedicels that are at first erect, but afterwards droop. This grows in dry places from Lake County to San Diego.

VI. ERIODIC′TYON, Yerba Santa

Low-branching erect shrubs. Leaves alternate, dentate, petioled, with the chief nerves pinnate, and the others forming a network. *Flowers in cymes, coiled at the tips, and generally collected in terminal clusters.* Corolla funnel-form, violet, purple, or white, without internal scales. Stamens with filaments adnate to the tube of the corolla. Styles 2, distinct at the base. *Capsule pointed, 2-celled, splitting on the back and at the sides into 4 hard, thick half-valves.*

a. **E. tomento′sum Benth.** The entire plant is white or rusty, with a dense coat of short woolly down. Southern California.
b. **E. glutino′sum Benth.** This is rather smooth and viscid, with a balsamic exudation. Throughout the Coast Mountains.

VII. HESPEROCHI′RON

Dwarf, stemless perennials with entire, spatulate, or oblong leaves. Flowers on naked, slender peduncles, shorter than the leaves, from the leaf axils. Calyx and corolla with the parts 5–7, the former with linear-lanceolate lobes which are sometimes unequal, the latter rotate or campanulate, white or purplish, with hairy base. Stamens inserted at the base of the corolla with hairy filaments. *Ovary cone-shaped, somewhat adnate to the calyx, tapering to the rather stout style which is 2-cleft at apex, with small stigmas. Ovary 1-celled. Seeds many.*

a. **H. Califor′nicus Watson.** Leaves many in a cluster at base. *Corolla oblong-campanulate, with the lobes longer than the tube*, about half an inch long. From California in the Sierra Nevada to Washington ; blooming as soon as the snow melts.

b. **H. pu′milus Porter.** Leaves fewer. *Corolla nearly rotate, its lobes longer than the tube which is densely bearded within*, about half an inch across. Same range and time of blooming as the preceding.

BORRAGINA′CEÆ, Borage Family

Herbs usually with stems and leaves, rough-hairy. Leaves alternate, entire, without stipules. Flowers in panicles, cymes, or racemes, coiled at the tips, usually on one side of the peduncles. Calyx 5-parted or cleft. Corolla salver-form. Stamens inserted on the tube of the corolla, alternating with its lobes. Ovules 4, solitary, at the base of the simple style, usually all ripening into 4 nutlets. The coiled flower clusters become straight as the flowers open.

I. HELIOTRO′PIUM, Heliotrope

Calyx 5-parted. Corolla funnel-form. Stamens with short filaments or none, and anthers sometimes cohering by their pointed tips. *Style simple or none, with an umbrella-shaped stigma.* Seeds with endosperm.

H. Curassa′vicum L. Smooth, glaucous, succulent, prostrate herbs, growing in moist, salty or alkaline places. Flowers white or pale violet in dense spikes, which are generally 2-forked. Widely distributed.

II. AMSINCK′IA, Fiddle-neck, Woolly Breeches

Hairy annuals, with conspicuous yellow or orange flowers in curved spikes or racemes without bracts. Many are covered with bristly hairs that have a pustulate base. Calyx 5-parted. Corolla funnel-form, with the tube longer than the calyx. Stamens with short filaments included in the corolla. Stigmas 2-lobed, capitate. Nutlets ovate-triangular, attached above the base to a narrow pyramidal column called the gynobase. The species are difficult to distinguish.

III. CYNOGLOS′SUM, Hound's Tongue, Forget-me-not

Calyx 5-parted, open in fruit. *Corolla tubular or salver-form, with conspicuous crests in the throat. Nutlets 4, covered over the back with short, stout prickles with barbed tips, forming burs.* These are rather coarse perennials, with large leaves and thick roots.

C. gran′de Dougl. Stems a foot or two high, branching above. Leaves mostly at the base on long petioles, oblong-ovate. Flowers in panicled racemes on a long naked peduncle. Corolla similar to the forget-me-not, but larger, at first pinkish, with white crests in the throat, turning blue after pollination. Monterey County to Washington.

IV. MERTEN′SIA, Bluebells

Stems erect, leafy, *not hispid, sometimes smooth.* Leaves broad, the upper ones sessile, the lower petioled. Flowers nodding, in cymes or panicled racemes. Corolla blue, often turning pink after pollination, trumpet-shaped or bell-shaped, with folds in the throat. *Nutlets sessile, on a flat or slightly convex receptacle.*

a. **M. oblongifo′lia Don.** Stems about a foot high, almost smooth. Leaves oblong or somewhat spatulate, rather succulent and with veins scarcely evident. *Corolla blue, with tube twice as long as the border, together about half an inch long.* Flowers in a close, terminal cluster. Stamens with the filaments as broad as the anthers and about the same length, inserted in the throat of the corolla. Blooming in early spring, growing on moist banks. Oregon to British Columbia.

b. **M. panicula′ta Don.** Stems 1–5 ft. high, more or less rough with pubescence. Leaves broad, veiny, ovate to oblong-lanceolate. Flowers blue, in loosely panicled racemes. *Corolla tube but little longer than the border, about as long as the hairy, linear, calyx divisions, together a half inch or more in length.* From Washington to the Arctic regions.

(Most of the other genera are in a state of confusion, because of the differences of opinion among botanists. The differences between them lie chiefly in the seeds, and they are difficult to distinguish.)

LABIA'TÆ, Mint Family

Herbs or shrubs with 4-angled stems and opposite leaves. Flowers generally in whorls, or solitary in the axils of the leaves. Calyx ribbed, with many nerves. Corolla 2-lipped. Stamens 4 in two sets, 2 often sterile. Fruit of 4 nutlets around a simple style. These plants are generally aromatic.

I. MEN'THA, Mint

Calyx 5-toothed. Corolla with short tube, naked within, and 4-cleft border, scarcely 2-lipped, but with the upper lobe broadest. *Stamens 4, nearly equal, erect, distant. Flowers small, white or purplish, in whorls.* Aromatic and sweet-scented herbs. (There are several cultivated species.)

a. **M. Canaden'sis L.** Flowers all in axillary whorls, the summit of the stem being flowerless. Calyx hairy. Common in damp places.
b. **M. Pule'gium L.** Covered with a white-woolly pubescence. Calyx slightly 2-lipped, 10-ribbed, the throat closed with hairs. Recently introduced, but spreading rapidly.

II. MONARDEL'LA

Calyx tubular, with 5 short, nearly equal teeth, and the throat naked within. Corolla with the tube longer than the calyx, smooth within ; upper lip 2-cleft, lower one 3-parted, with flat, oblong-linear lobes. *Stamens 4, projecting beyond the corolla. Flowers in terminal heads having conspicuous involucres.*

a. **M. villo'sa Benth.** *Perennial* herbs with many stems from a woody base, soft-hairy. *Leaves ovate, strongly veined.* Bracts of the involucre similar to the leaves. Flowers flesh-color, white, or most frequently purple. Widely distributed, and blooming at all seasons.
b. **M. odoratis'sima Benth.** *Perennial* with several stems from a woody root, 6–12 in. high, pale green or gray with a minute pubescence. Leaves *oblong to lanceolate, entire, on short petioles, with veins inconspicuous.* Bracts thin and membranous, veiny, white or purple. Calyx teeth hairy. Common in the mountains of California and extending to Washington.

c. **M. lanceola′ta Gray.** *Annual,* with stems loosely branching, a foot or more high, green and almost smooth. Leaves oblong or lanceolate, tapering into a slender petiole. *Bracts ovate or ovate-lanceolate, with cross veinlets between the principal veins. Corolla purple;* calyx teeth acute, densely hirsute within, almost smooth without. Throughout California in the valleys and plains.

d. **M. can′dicans Benth.** Annual, gray, with soft pubescence. Leaves lanceolate to narrowly oblong, obtuse, tapering to a petiole. *Bracts ovate, somewhat papery, white with greenish nerves; cross veinlets between the principal nerves. Corolla white, small and short;* calyx teeth short, obtuse, tipped with white wool on both sides. Through middle and southern California.

III. MICROME′RIA, Yerba Buena

Calyx tubular, equally 5-toothed. Corolla short, naked within; *upper lip erect, entire or notched, lower spreading, 3-parted. Stamens 4.* These are sweet-scented plants, with small lavender flowers in the axils of the leaves.

M. Douglas′ii Benth. Perennial herbs, spreading by trailing stems. Leaves round-ovate, sparingly toothed. This usually grows in the shade of bushes and trees in the Coast Mountains.

IV. SPHA′CELE

Calyx bell-shaped, 5-cleft, thin, membranous, enlarged in fruit and persistent. Corolla oblong, bell-shaped, with 5 broad and roundish, erect lobes, and a hairy ring at the base of the tube within. *Stamens 4, distant, one pair shorter.*

S. calyci′na Benth. Shrubby at base, with many leafy stems. Flowers an inch long, solitary in the upper axils, forming a raceme. Corolla white or tinged with purple. The entire plant has a sweet aromatic perfume. From middle California southward.

V. SAL′VIA, Sage

Ours are all herbs. Calyx 2-lipped, with the upper lip 2 or 3 toothed, lower 2-cleft. Corolla deeply 2-lipped, with the upper lip erect, entire, notched, or rarely 2-lobed. *Stamens 2, with filaments apparently forked, one end bearing a linear* *anther cell, the other end a mere rudiment of an anther cell.* The nutlets when wet become mucilaginous and send out spiral threads.

a. **S. cardua′cea Benth.** THISTLE SAGE. *Leaves clustered at the root, white-woolly, thistle-like.* Flowers in whorls. *Corollas large, bright blue.* This is a very showy plant of the interior valleys of California.

b. **S. Columba′riæ Benth.** CHIA. *Leaves wrinkled with numerous veins, once or twice parted into oblong, crenate or toothed divisions.* Flowers in one or more rather distant whorls on the naked stems. *Corolla rather small, dark blue.* Involucre of entire leaves, like bracts. Widely distributed.

VI. AUDIBER′TIA, California Sage, Bee Sage

Shrubby plants with leaves wrinkled and veiny, finely crenate. Flowers similar to those of *Salvia*, except that the *filament has but one linear anther cell, and shows the remains of the connective as a sort of spur.* The various kinds of sage, so well known as honey plants, all belong to this genus. They are most abundant in southern California, where they sometimes clothe the hillsides.

* *Flowers in dense whorls at intervals along the stem. Bracts crowded and conspicuous. Shrubs.*

a. **A. niv′ea Benth.** WHITE SAGE. Stems and leaves covered with a snow-white down. Whorls an inch across, usually 2–4. Corolla lavender or lilac, with the tube scarcely longer than the lips. Stamens and style conspicuously extending beyond the corolla. The bracts and the calyx teeth are blunt.

b. **A. stachyoi′des Benth.** BLACK SAGE. Stems and leaves ashy gray, becoming greener and smoother with age. Clusters of flowers 3–5 at long intervals, on slender stems. Corolla lavender, half an inch long. Calyx teeth and bracts bristle-tipped.

** *Flowers in a close panicle. Floral leaves and bracts of the small and numerous clusters lance-shaped or awl-shaped. Shrubs.*

c. **A. polystach′ya Benth.** WHITE SAGE, GREASE WOOD. Stems many, erect, covered with a fine white down; inflorescence a foot or so in length; flowers nearly sessile. Calyx with the upper lip broad, the lower with 3 long teeth. Corolla half an inch or more long, white or lavender, with a short tube and broad lower lip. Stamens and styles long, conspicuously exserted. This is said to be the best honey sage.

*** *Flowers large, in dense whorls. Woody only at base.*

d. **A. grandiflo'ra Benth.** Stem stout, 2–3 ft. high, woolly and glandular. Leaves wrinkled, white tomentose on the lower surface, sinuate-crenate. The lower ones are broadly lanceolate, with the base somewhat arrow-shaped, 3–8 in. long on margined petioles; the upper are oblong and sessile. Corolla $1\frac{1}{2}$ in. long, bright red, with tube longer than the limb. Bracts broad and membranaceous. Stamens extending beyond the corolla. This is common from near San Francisco southward. It generally grows in the hills.

VII. SCUTELLA'RIA, Skullcap

Low perennial herbs, with flowers in the axils of the leaves on short peduncles. *Calyx helmet-shaped. Corolla with an arched upper lip and dilated throat. Stamens 4, the lower pair with 1-celled anthers, the upper with 2-celled bearded anthers.*

a. **S. tubero'sa Benth.** *Low from slender underground stems terminating in small tubers.* Leaves ovate, toothed, on slender petioles. *Flowers dark blue*, over half an inch long. From Santa Barbara County northward.

b. **S. Califor'nica Gray.** *Stems several, from slender rootstocks.* Leaves entire, narrowed at base. *Flowers yellowish white*, about two-thirds of an inch long. Northern California to Oregon.

c. **S. angustifo'lia Pursh.** Stems erect, leafy. *Leaves oblong to linear, mostly sessile, entire, except for a few teeth on the lower ones.* Pedicels as long as the calyx. Corolla nearly an inch long with slender tube and dilated throat; lower lip woolly within. Throughout California to British Columbia.

d. **S. galericula'ta L.** Stems slender, 1–3 ft. high, simple or branched above. *Leaves ovate-lanceolate, almost sessile, serrate, except at the top. Corolla dark blue*, less than 1 in. long. Widely distributed. Summer.

VIII. BRUNEL'LA, Self-heal

Perennial herbs with usually simple stems and sessile, 3-flowered flower-clusters in the axils of kidney-shaped bracts, the whole forming a spike or head. Calyx tubular, bell-shaped, somewhat 10-ribbed, upper lip broad, 3-toothed, the teeth short; lower lip with 2 longer teeth. Upper lip of the corolla upright, arched, and entire, the lower spreading, reflexed, fringed, and 3-cleft. *Stamens 4, reaching up under the upper lip, with the tips of the filaments 2-toothed, only one tooth anther-bearing.*

B. vulga'ris L. SELF-HEAL, HEAL-ALL, CARPENTER WEED. Leaves with petioles, ovate-oblong, either entire or toothed, often somewhat hairy; corolla usually dark-blue or purplish, somewhat longer than the brown-purple calyx. This is often abundant in damp places, and is widely distributed.

IX. MARRU'BIUM, Horehound

Perennial herbs with many stems, forming a clump a foot or two high, white-woolly. Calyx *with usually 10 nerves and teeth, the alternate ones spiny-tipped and recurved.* Corolla with upper lip narrow, arched and 2-lobed; lower spreading and 3-cleft. *Stamens 4, having anthers with the 2 cells not distinct.* Flowers in dense whorls, in the axils of the upper leaves. This is a widely spread, introduced plant.

M. vulga're L. Leaves roundish, wrinkled, crenate. Corolla small and white. The bitter aromatic juice is used as a remedy for colds.

X. STA'CHYS, Hedge Nettle

Perennial herbs with a disagreeable odor,—some species growing near water becoming very tall. Flowers nearly sessile, in scattered whorls, purplish or white. Calyx 5-toothed, 5–10-nerved. *Corolla with tube not dilated at the throat, the upper lip erect, arched, entire or notched, lower spreading, 3-lobed, the middle lobe longest. Stamens 4, with 2-celled anthers.*

a. **S. bulla'ta Benth.** Stems one or several, loosely branching, rough with downward-pointing hairs. Leaves ovate, cordate, crenate, obtuse, with petioles an inch or two long. *Flowers red-purple, in whorls, forming an interrupted spike.* This grows everywhere in California, and blooms almost throughout the year.

b. **S. al'bens Gray.** Stems erect, 1–5 ft. high, clothed throughout with soft white wool. Leaves oblong, cordate at base, crenate, 2–3 in. long; upper sessile; lower with short petioles. *Flowers whit on a wand-like spike in dense interrupted close clusters.* Calyx with spine-tipped teeth nearly equaling the tube of the corolla. California in the Sierra Nevada Mountains and hills of southern California.

c. **S. Chamisso'nis Benth.** Stems erect, 2–6 ft. high, with stiff hairs pointing downwards, on the angles. Leaves oblong-ovate, 3–5 in. long, crenate, wrinkled with the veins, whitish, with woolly hairs on the lower surface, stiffer ones on the upper. Spike 6–12 in. long. *Calyx with spine-tipped teeth, densely hairy.* Corolla purplish, $\frac{3}{4}$ in. long, hairy; lower lip half as long. A very showy species along the Californian coast from San Francisco northward.

d. **S. cilia'ta Dougl.** Similar to the above, but with the leaves greener and thinner; corolla smaller, with the tube smooth. Along the coast of Oregon and Washington.

XI. TRICHOSTE'MA, Blue-curls, Camphor Weed

Shrubs or herbs with flowers in dense, usually one-sided axillary cymes, stamens and corolla blue or purple (rarely white). Calyx bell-shaped, almost equally 5-cleft. Corolla with a slender tube, 5-parted, the divisions forming in bud a roundish ball which encloses the coiled stamens. *Stamens spirally coiled in the bud, conspicuously protruding from the open corolla.* In bloom in summer and fall.

a. **T. lanceola'tum Benth.** CAMPHOR WEED. Annual herbs with several branches, erect from the base. *Leaves crowded, sessile, lance-shaped.* Cymes almost sessile, conspicuously one-sided, densely flowered. Corolla and calyx somewhat hairy or woolly. This plant is called camphor weed, because it has a strong odor somewhat like camphor, but very disagreeable, sometimes causing headache. Widely distributed in the interior valleys.

b. **T. lax'um Gray.** Annual, diffusely branched, soft, pubescent. *Leaves few, lanceolate-oblong, narrowed to an obtuse apex, 2–3 in. long, on slender petioles.* Cymes loosely flowered, on peduncles. Common from middle to northern California, growing in dry places.

c. **T. lana'tum Benth.** ROMERO. Shrubby, 3 or 4 ft. high. Leaves numerous, narrowly linear, with margins turned under, smooth and shiny above, white-woolly on the under surface. Flowers in numerous cymes in a close terminal cluster, destitute of bracts. *The whole inflorescence, even to the calyx and corolla, is covered with dense violet wool.* The filaments extend an inch or more beyond the corolla. Southern California, in rocky places. It is very conspicuous and beautiful.

SOLANA′CEÆ, Nightshade Family

Herbs or shrubs with leaves alternate and without stipules. Flowers regular, with the parts in fives, except the single style and 2-celled ovary. Fruit a many-seeded berry or capsule. Seeds with curved embryo and endosperm. This family contains Tobacco, Tomato, Nightshade, Egg-plant, Potato, and Chili-pepper.

I. SOLA′NUM, Nightshade, Potato

Corolla wheel-shaped, 5-parted or cleft. *Stamens with short filaments and distinct anthers,* which often apparently unite around the style. Fruit usually a berry.

a. **S. Douglas′ii Dunal.** Somewhat shrubby, widely branching or even climbing by the rough angles of the branchlets. Leaves ovate, entire, or with large teeth, 1–2 in. long. *Corolla white or bluish, small. Berries black.* Common throughout California, near the coast.

b. **S. ni′grum L.** Common Nightshade. Annual, with stems branching diffusely. *Corolla small, white. Berries black when ripe,* as large as peas, in numerous umbels on axillary peduncles. This is common everywhere in waste ground.

c. **S. umbellif′erum Esch.** Shrubby at base, much branched, with leaves and stems hoary. *Flowers in umbels, the corolla bluish purple, $\frac{3}{4}$ in. in diameter.* The leaves vary extremely. Widely distributed.

d. **S. Xan′ti Gray.** Similar to the above, but either smooth or glandular-hairy; leaves thin. *Corolla generally larger.* This is more common in southern California.

II. DATU′RA, Thorn-apple

Stout, widely branching herbs with rank odor and narcotic-poisonous qualities. Flowers large, on short stems from the axils of the leaves. Calyx tubular, 5-toothed, deciduous, leaving a circular disk under the fruit. *Corolla broadly funnel-form, convolute in the bud.* Pistils with long style and 2-lipped stigma. *Capsule prickly all over.* Seeds large, kidney-shaped.

D. meteloi'des DC. Perennial, spreading, and often tall, hoary Leaves unequally ovate, wavy on the margin, or entire. Corolla white or pale violet, with the border broadly expanded, the 5 angles terminating in long, slender awns. Pods large on recurved peduncles. Southern California.

III. NICOTIA'NA, Tobacco

Herbs (one a tree) with rank odor and narcotic poisonous properties. Calyx bell-shaped, 5-toothed or lobed, closely surrounding the capsule. *Corolla salver-form or funnel-form, with a very long tube.* Stamens with slender filaments and broad anthers included in the tube of the corolla. Pistil with long, slender style and 2-celled ovary, stigma 2-lobed or cap-like. *Capsule splitting generally at the junction of the valves and on the back, appearing 4-celled.*

a. **N. glau'ca Graham.** Tree Tobacco. This has been introduced from South America, and is now widely distributed in southern California. It is a shrub or small tree with pale-green foliage. Flowers in loose terminal panicles; corolla 2 in. long, greenish yellow, with a long tube, narrowed at the throat; border erect, 5-crenate.

b. **N. attenua'ta Torr.** Stems simple or branching, very viscid. Leaves oblong-lanceolate, pointed at both ends. Flowers in loose, terminal racemes. Calyx teeth short, triangular, acute. *Corolla white, narrow, salver-form, the tube an inch long and the border ½ in. across.* Pod exceeding the calyx. This is widely distributed and is frequently found along highways.

c. **N. Bigelo'vii Wats.** Similar to the preceding but with sessile leaves. Calyx with unequal lobes, *corolla tubular, funnel-form, with tube an inch or more long and the border an inch across;* pod shorter than the calyx. This is also found along highways.

SCROPHULARIA'CEÆ, Figwort Family

Herbs and shrubs with corolla 2-lipped or otherwise more or less irregular (2 lobes belong to the upper lip of the corolla; 3 to the lower). Stamens 2 or 4 (2 long and 2 short), or 5, with one lacking the anther. Pistil with a simple style and 2-celled ovary. Fruit a 2-celled pod, with the seeds on an axillary placenta, splitting from the top.

I. VERON′ICA, Speedwell

Low herbs with opposite leaves, and flowers in axillary racemes cr solitary. Calyx and corolla 4-parted, with the lobes more or less unequal. Stamens 2. *Pod inversely heart-shaped.*

a. **V. America′na Schweinitz.** Smooth herbs growing in wet places, with the stems rooting at the joints. Leaves ovate or oblong, on petioles. *Flowers numerous, small, bright blue* with darker stripes. Widely distributed.

b. **V. peregri′na L.** Annual, 3–10 in. high, erect, with few branches. Lower leaves opposite, upper alternate, linear-oblong, obtuse, entire or toothed. Flowers on short pedicels in the leaf axils. *Corolla very small, white.* Capsule many-seeded. Common, apparently an introduced weed.

II. SCROPHULA′RIA, Figwort, Bee-plant

Perennial herbs with opposite leaves, and small flowers in loose cymes arranged in a terminal panicle. Calyx 5-cleft, with broad, rounded lobes. *Corolla with a globular tube and 5 lobes; four are erect and the fifth turned down or spreading. Stamens 4 in 2 pairs,* shorter than the lobes of the corolla and inserted low on the tube. A rudiment of a fifth stamen appears in the form of a scale on the upper side of the throat of the corolla.

S. Califor′nica Cham. CALIFORNIAN BEE-PLANT. Stems 2–5 ft. high, nearly smooth. Leaves oblong-ovate, usually cordate at base, coarsely doubly toothed or incised. *Flowers brownish purple,* less than half an inch long, the rudimentary stamen narrowly wedge-shaped or spatulate. The honey-glands produce a large quantity of honey which can usually be seen within the corolla tube. This is widely distributed and common.

III. COLLIN′SIA

Low annual herbs with opposite leaves, and flowers somewhat resembling pea blossoms. *Corolla 2-lipped, with the lower lip 3-lobed and the middle lobe compressed at the sides, including the style and stamens; tube short, with a protuberance at the base on the upper side, the mouth closed by an* *inward projection of the lower lip like a palate.* Stamens 4; a small gland at the base of the corolla on the upper side answers to the fifth stamen.

a. **C. bi′color Benth.** A foot or so high; leaves more or less toothed, the upper ovate-lanceolate, and sessile by a broad base. *Flowers on short pedicels, in racemes at the summit of the stem;* corolla with the upper lip nearly white, the lower rose-color. Widely distributed in California.

b. **C. Francisca′na Bioletti.** Similar to the last, but the flowers are on longer pedicels, more numerous in the whorls; and the *throat of the corolla is entirely closed by the palate.* This grows around San Francisco and is very common.

c. **C. tincto′ria Hartweg.** Flowers almost sessile. Corolla yellowish or white, marked with purple dots or lines, the upper lip and its lobes very short. *The plant is covered with a yellowish or brownish glandular pubescence that stains the hands.* This is common in the foothills of the Sierras.

d. **C. bartsiæfo′lia Benth.** *Leaves thickish in texture, linear to ovate-oblong, crenate.* Flowers on short pedicels, crowded in the axils of the leaves or bracts. Corolla nearly white, with the throat bearded, and longer than broad, upper lip about the length of the curved throat. This grows in sandy soil in the central and western parts of California.

e. **C. parviflo′ra Dougl.** Stems slender, branching, 2–6 in. high, leaves lanceolate or oblong, narrowed at base and entire, sometimes whorled. Flowers on slender pedicels, solitary or several in a whorl. *Flowers small, less than ¼ in. long.* Corolla blue and white, a little longer than the narrow, triangular calyx lobes. Common in the Sierra Nevada range and north to British Columbia. In bloom early.

IV. PENTSTE′MON

Perennial herbs with opposite leaves, the upper sessile or partly clasping. Calyx 5-parted. Corolla red, purple, blue, white (rarely yellow), 2-lipped, with a more or less inflated tube; upper lip 2-lobed, lower 3-cleft or spreading. *Stamens 4, the fifth a conspicuous filament without an anther.* Pod usually pointed, splitting from the top into two parts.

a. **P. cordifo′lius Benth.** Stems very leafy, climbing over bushes by long branches. Leaves cordate, serrate, or toothed. Flowers in a leafy panicle. *Corolla scarlet, with a long narrow tube. Sterile filament bearded.* Common in southern California.

b. **P. heterophyl'lus Lindl.** Stems many from a woody base, pale-green. Leaves lance-shaped or linear. *Corolla rose-purple, an inch long. Anthers shaped like a horseshoe, with the base of each cell remaining closed, and forming a sac, ciliate on the opened edges. Sterile filament smooth.* Throughout California in dry places.

c. **P. centranthifo'lius Benth.** Light bluish green and perfectly smooth. Upper leaves heart-shaped, clasping. *Corolla fully an inch long, bright red, tubular, hardly bilabiate, with the lobes spreading but little. Sterile filament slender and smooth.* Most common in southern California.

d. **P. gla'ber Pursh.** Stems 1–2 ft. high, smooth, glaucous. Upper leaves ovate-lanceolate, clasping the stem. Flowers in a long, close panicle. Sepals ovate, pointed. Corolla violet, with swelling throat, 1–1½ in. long. *Sterile filament with a few hairs at top. Anthers opening from the base of each cell to the apex, smooth or slightly hairy.* Along streams. Summer.

e. **P. confer'tus var. cæruleo-purpureus Gray.** Stems slender, erect, smooth, except for the viscid pubescence about the flowers. Leaves linear to lanceolate. Flowers rather small, in 2–5 whorls, 1 in. or more apart. Sepals with papery, fringed margins and pointed tips. Corolla purplish blue, 2-lipped, the lower lip bearded. *Anthers opening from base to apex, the two valves spreading out flat, after the pollen has been discharged. Sterile filament bearded.* In the mountains. Summer.

V. CASTILLE'JA, Indian Paint-brush

Perennial herbs generally with several stems from woody roots. Leaves sessile. *Flowers in simple spikes, with the bracts large and colored red, white, or yellowish. Calyx colored like the bracts, tubular, more or less cleft either in front or behind or on both sides.* Corolla tubular, with a long-pointed upper lip, lower lip very small, 3-toothed, with 3 folds or small sacs below the short teeth (the tube is usually enclosed in the calyx). *Stamens 4, enclosed in the upper lip.* Style long, with stigma cap-shaped or 2-lobed.

a. **C. affi'nis Hook & Arn.** Stems often tall, branched from the base. Leaves simple, linear-lanceolate, entire. Flowers somewhat distant below but crowded above, curved. Upper leaves, bracts, and calyx more or less colored red. *Corolla yellowish or reddish, an inch or more long, curved, surpassing the red calyx,* the lower lip very short. Middle to southern California.

b. **C. foliolo'sa Hook & Arn.** *Stems generally in a bunch, white-woolly.* Leaves short but numerous, lowest entire, upper floral leaves cleft, with the tips dilated, yellowish or red. This is common only on dry hills of the Coast Mountains.

c. **C. latifo'lia Hook & Arn.** Stems leafy, 1 to several from the root, viscid-pubescent. *Leaves short and broad, the upper ones 3–5-lobed, tinged with red.* Calyx lobes longer than the tube of the corolla. Near the coast, from Monterey County northward.

VI. ORTHOCAR'PUS, Owl's Clover

Low annual herbs, similar to *Castilleia* in having spikes of flowers with the cleft bracts and calyx divisions colored. Calyx short, tubular, 4-cleft. *Corolla tubular, with the upper lip hardly longer than the lower, small in comparison with the lower, which is inflated and in several species has 3 round sacs.*

* *Bracts with tips colored like a corolla.*

a. **O. purpuras'cens Benth.** Escobita. Simple and erect, or branched at the base, hairy. Spike dense, oblong, the lobed bracts and the calyx divisions crimson. *Upper lip of the corolla densely bearded with crimson hairs, hooked at the apex, the lower lip with 3 very small sacs.* Stigma large, globose, densely covered with purple hairs. Very common in spring. Widely distributed.

b. **O. densiflo'rus Benth.** Owl's-clover. This is similar to the above, except that *the upper lip of the corolla is straight and the lobes of the bracts and of the calyx white and crimson;* the leaves are soft, pubescent, with few lobes, or entire at the base. Along the coast.

** *Bracts not colored like a corolla.*

c. **O. erian'thus Benth.** Slender, with many branches; stems and bracts dark red. *Corolla deep yellow, the upper lip slender, pointed, dark-purple, the sacs on the lower lip large, round, and deep, the tube very slender.* Monterey County northward.

d. **O. versi'color Greene.** Pop-corn Flower. Similar to the last, *but the flowers are pure white, fading pinkish.* In one variety the flowers are rose-color from the first. This species is very fragrant. Around San Francisco.

e. **O. lithospermoi'des Benth.** Stems rather stout, generally simple, 1–1½ ft. high, very leafy. Flowers in a dense spike. Calyx lobes linear. *Corolla deep yellow, fading whitish, an inch or more long, with 3 large sacs.* This blooms later than the others. Throughout California.

There are many species besides these.

VII. PEDICULA'RIS

Perennials with one to several stems from a thick root. Leaves pinnately divided or lobed, the divisions often toothed, cleft, or divided. Calyx 2–5-toothed, irregular. *Corolla 2-lipped, the upper arched and compressed on the sides, sometimes with a beak; the lower erect at base, 3-lobed, and with 2 crests above.* Stamens 4, in the long upper lip.

P. densiflo'ra Benth. Indian Warrior. Leaves twice pinnately divided, with the divisions sharply and irregularly incised. Stem and leaves dark-red when young, becoming greener with age. Flowers an inch long, crimson, in a dense spike that lengthens in fruit. Common in western and middle California.

VIII. MIM'ULUS, Monkey Flower

Herbs, or one species shrubby, with opposite, simple leaves and showy flowers on axillary peduncles. Calyx bell-shaped, 5-toothed, and with as many folds and angles, often oblique. *Corolla with the tube included in the calyx and the border with 5 round, spreading lobes arranged so that 2 form the upper lip and 3 the lower.* Within the tube are two ridges flattened on top, running down the lower side of the throat. Stamens 4, with the anther cells diverging. *Stigma 2-lobed, with spreading parts, often somewhat shield-shaped.* When an insect alights it touches the stigma, which immediately closes, the 2 lips folding together; the anthers are thus exposed, so that the insect becomes dusted with pollen. This can be observed by touching the stigma with a pencil.

a. **M. cardina'lis Dougl.** Red Monkey Flower. Stout; 2–4 ft. high, viscid-pubescent. Leaves sessile, ovate, dentate, 2 in. long. *Corolla scarlet, 2 in. long, with all the lobes except the upper one reflexed.* Stamens projecting from the corolla. This grows along streams. Widely distributed.

b. **M. Lewis′ii Pursh.** Perennial, with erect, rather slender stems, 1–2 ft. high, or more. Leaves lanceolate-ovate, with the margin finely toothed. *Corolla rose-red, 2 in. long, the border of roundish, spreading lobes.* Stamens included within the corolla. This is one of the handsomest species. It grows in shady, moist places from British Columbia through California, in the mountains.

c. **M. brev′ipes Benth.** Annual, 1–2 ft. high, viscid-pubescent. Leaves lanceolate to linear, 1–4 in. long. Calyx teeth unequal, pointed. *Corolla yellow, 1½ in. long, the border campanulate, an inch across, with rounded lobes.* From Monterey southward.

d. **M. Bolan′deri Gray.** *Annual, with stems about a foot high, viscid-pubescent.* Leaves oblong, 1–2 in. long. *Corolla crimson, an inch long, tubular, with the border slightly spreading.* This is common in the foothill region of the Sierra Nevada through California.

e. **M. moscha′tus Dougl.** Musk-plant. Perennial, with low, spreading stems, *soft-hairy, musk-scented. Corolla light yellow,* ½ in. long. This grows in wet place and roots at the joints of the stem. Widely distributed.

f. **M. Langsdor′ffii Don.** Annual or perennial, the former slender, the latter stout, growing in wet places and rooting at the joints of the lower parts of the stem. Stem leaves round, clasping; root leaves on petioles, with a roundish blade at the top and a few small leaflets below. *Corolla yellow, with brown or red spots, decidedly 2-lipped, large, from 1 to 1½ in. long.* Widely distributed and extremely variable.

g. **M. tri′color Lindl. (Euna′nus Benth.).** Low, with spreading, leafy branches. *Corolla 2 in. long, with a short, slender tube and wide border of almost equal lobes, rose-purple, marked with deep crimson, and with yellow throat.* This is a very beautiful plant, and grows in low, damp places. From middle California northward.

h. **M. Douglas′ii Gray (Euna′nus Benth.).** Erect, with stems beginning to flower when an inch or so high. *Corolla crimson, decidedly 2-lipped, the lower lip wanting, or much shorter than the upper lip;* tube from 1 to 1½ in. long; throat funnel-form, dilated. Throughout California, in bloom usually very early.

i. **M. glutino′sus Wendland (Dip′lacus Nutt.).** *Shrubby,* 3–6 ft. high, with glutinous, evergreen foliage. Leaves opposite, serrate, veiny. *Flowers yellow or reddish, large and showy, solitary, on pedicels in the leaf axils.* This is common throughout California, and has many forms regarded as species by good botanists.

j. **M. exi′lis Dur.** Annual, erect, with branched stems about a foot high, leafy and soft-hairy, *somewhat viscid, flowering from the first.* Leaves lanceolate, sessile, entire, the lower longer than the upper and shorter than the pedicels. Calyx 5-cleft, bell-shaped, the tube without angles and almost without nerves. *Corolla a little* *longer than the calyx, yellow, with nearly equal lobes and sometimes some brown spots in the throat.* Common throughout California in the dry beds of streams.

OROBANCHA′CEÆ. Broom Rape Family

Root parasites, tuberous, pale or brownish in color, with scales in place of leaves. Corolla 2-lipped. Stamens 4, in 2 sets. Ovary 1-celled, with parietal placentæ. Seeds many, very small. Style long, with stigma 2-lobed. Pod splitting into 2 valves when ripe, each valve with 1 or 2 placentæ.

APHYL′LON, Cancer Root

Flowers yellowish or purplish, usually on peduncles. Stamens included in the somewhat 2-lipped corolla. Calyx with 5, nearly equal, pointed lobes. Stigma shield-shaped or with 2 broad, flat lobes. Placentæ, a pair to each valve. Anther cells deeply separated from below, awned at the base.

a. **A. uniflo′rum Gray.** Stem very short, bearing one or a few slender scapes a few inches high. *Flowers violet and violet scented, terminating the scapes.* Frequent in California and north to British Columbia.

b. **A. fascicula′tum Gray.** Stems rather slender, nearly as long as the numerous fascicled peduncles. *Flowers brownish or yellowish.* Widely distributed.

PLANTAGINA′CEÆ. Plantain Family

Herbs with the leaves and peduncled spikes all from the root. Corollas papery, 4-cleft.

PLANTA′GO, Plantain

Flowers perfect, each with a bract below. Calyx of 4 persistent sepals free from the ovary. Corolla greenish or dull white. Stamens 2–4, with long filaments. Fruit a capsule opening by a lid which falls off, carrying with it the placenta with the shield-shaped seeds attached.

a. **P. ma′jor L.** Common Plantain. *Leaves large, ovate, 5–7-ribbed, the petioles channeled on the upper side.* A wayside weed, introduced.

b. **P. lanceola′ta L.** Hairy. *Leaves long, lanceolate, 3–7-ribbed. Flowers with conspicuous stamens;* at first in a head, lengthening to a spike. Introduced.

c. **P. marit′ima L.** *Smooth, leaves linear, fleshy.* Spike oblong. This is found along the seashore.

d. **P. Patago′nica Jacq.** *A small annual covered with white silky wool.* Scape 2–3 in. high. Flowers in dense oblong spikes, except in very small plants, where they form a head. Widely distributed. This has been made to include many species which are difficult to distinguish.

RUBIA′CEÆ. Madder Family

Herbs or shrubs with opposite, entire leaves with stipules; or whorled leaves without stipules. Calyx and corolla 4-lobed, adnate to the ovary. Stamens distinct, alternate with the lobes of the corolla and borne on its tube. Ovary 2–5-celled. Seeds with endosperm. The plants yielding coffee and quinine belong to this family.

I. CEPHALAN′THUS, Button Willow

Shrub growing near water, with willow-like leaves, opposite or whorled; and scale-like stipules within the petioles. Flowers in a dense, round head. Calyx pointed at base, 4-toothed. Corolla with a long, slender tube and a small, 4-cleft border. Stamens short. Style long, conspicuous, with a cap-like stigma. Capsule, when ripe, splitting from the base upward into 2–4, closed, 1-seeded parts.

C. occidenta′lis L. Leaves lanceolate, 3–5 in. long. Heads an inch in diameter, flowers cream-color. Common along streams throughout California, except near the coast.

II. KELLOG′GIA

Low, slender, much-branched herbs. Leaves opposite, with stipules between the petioles. *Flowers small, dull purple, in loose cymes.* Calyx tube somewhat flattened, covered with stiff, short bristles. Corolla funnel-form with narrow lobes. Stamens 4, on the throat of the corolla. Style slender ; stigmas 2, thread-like. Fruit covered with hooked bristles, splitting into 2 parts, to the walls of which the seeds adhere.

K. galioi′des Torr. This grows in damp, shady places in the Sierra Nevada Mountains, chiefly northward.

III. GA′LIUM, Bedstraw, Cleavers

Herbs with slender stems, whorled leaves, and no stipules. Flowers small, white or greenish. Calyx without a border. Corolla wheel-shaped, 4-parted. Stamens short ; styles 2, short, with cap-like stigmas. Fruit dry or fleshy, of 2 similar rounded parts with 1 seed in each.

* *Fruit a berry. Perennials.*

a. **G. Califor′nicum Hook. & Arn.** Stems low, generally growing in bunches. *Leaves thin, oval, with a bristle-tipped apex ; margin and midrib with stiff hairs.* Fruit pearly white when ripe, turning black when dried, smooth, on recurved pedicels. Common from San Francisco southward.

b. **G. Nuttal′lii Gray.** *Shrubby, climbing over the bushes, with a tangled mass of slender stems* which are minutely spiny on the angles. Common throughout California near the coast.

c. **G. Andrews′ii Gray.** Low, densely matted, nearly smooth, with *leaves bright, shining green, crowded, somewhat spine-tipped. Flowers diœcious,* the sterile in few-flowered cymes, the fertile solitary. The dead stems and leaves are persistent and usually become white.

** *Fruit dry.*

d. **G. Apari′ne L.** Annual, climbing by the reflexed prickles of the stem and leaves. *Fruit on straight pedicels, densely covered with hooked prickles forming a bur.* Common.

e. **G. triflo′rum Michx.** Waldmeister. Stems with the odor of vanilla when dry, weak, spreading on the ground. Leaves 6 in a whorl, elliptical, acute at both ends, having a few short, reflexed prickles on the margins and midribs. *Peduncles few, 3-forked;* flowers greenish white, on spreading pedicels. Fruit covered with slender, hooked bristles. This grows in the woods from San Francisco northward.

f. **G. borea′le L.** Erect, smooth, leafy, branched. Leaves in fours, linear to lanceolate, obtuse, 3-nerved. *Flowers white, perfect, in a terminal panicle.* Fruit small, hispid at first, smooth when ripe. In the mountains northward. Summer.

CAPRIFOLIA′CEÆ. Honeysuckle Family

Shrubs or shrubby vines (rarely herbs) with opposite leaves without stipules. Flowers perfect, regular or irregular. Calyx 5-toothed, adnate to the inferior ovary. Corolla 4 or 5 cleft. Stamens distinct, as many as the corolla lobes and alternating with them. Ovary 2–5-celled. Fruit a berry, drupe or capsule.

I. SYMPHORICAR′POS, Snowberry

Low, branching shrubs, with leaves usually entire (sometimes on young shoots lobed at the base). Flowers in axillary or terminal spikes or clusters with 2 bracts under each flower. Calyx 5-toothed, persisting on the fruit. Corolla bell-shaped, 5 or 4 lobed. *Fruit a roundish, white berry containing 2 bony nutlets.* The berries are usually densely clustered at the ends of the branchlets.

a. **S. racemo′sus Michx.** *Erect shrubs, smooth or with the lower face of the leaves pubescent.* Flowers in terminal, short and interrupted spike-like racemes, or some solitary in the upper axils. Corolla very hairy within at the base of the lobes. Style and stamens short. Widely distributed.

b. **S. mol′lis Nutt.** *Low,, diffusely spreading, softly and densely pubescent.* Leaves oval, small. Flowers few in terminal clusters or in the upper axils. Corolla short and broad, but little bearded inside. Throughout California.

II. LONIC′ERA, Honeysuckle, Twin-berry

Twining or erect shrubs with entire leaves (sometimes lobed on short shoots), the upper united around the stem in some species. Flowers many in interrupted spikes, or axillary in pairs which are sessile in an involucre. Calyx minutely 5-toothed. *Corolla tubular, funnel-form, or oblong bell-shaped, with the border 5-lobed; or 2-lipped, with 4 lobes forming the* *upper and 1 the lower lip.* Ovary 2 or 3 celled, with numerous ovules in each cell. Style slender, tipped by a cap-like stigma.

a. **L. hispid'ula Dougl.** Twining, with the broad floral leaves, uniting around the stem, the others elliptical, all except the lowest with broad stipule-like appendages, all bluish green and pale. *Spikes of 3–6 whorls of pink flowers with the corollas 2-lipped. Fruit a red berry, somewhat viscid.* Along the coast.

b. **L. interrup'ta Benth.** Stoutish, erect and bushy, less disposed to twine, branches covered with shining white bark. Leaves pale-green, nearly round, all without stipules, several of the upper pairs uniting. Spikes of several interrupted whorls. *Flowers yellow, smooth.* Inner Coast Mountains and foothills of the Sierra Nevada.

c. **L. involucra'ta Banks.** *Shrubs with stems erect, never twining, and leaves never united.* Flowers in pairs on an axillary peduncle, each pair contained in a leafy involucre of 2 bracts. Corolla yellowish, funnel-form, swollen at the base. *Berries close together, black when ripe, the involucre becoming dark red, with the lobes reflexed.* Widely distributed.

d. **L. cilio'sa Poir.** *Stems low, or climbing.* Leaves broadly ovate, glaucous beneath, generally smooth except for the ciliate margin; the uppermost one or two pairs united to form a disk. Whorls of flowers 1–3, generally terminal but sometimes from the lower leaf axils. *Corolla smooth, an inch or more long, trumpet-shaped, scarlet without, yellow within; the tube swollen on one side near the base; the border slightly 2-lipped.* From the Sierra Nevada Mountains of middle California to British Columbia.

III. SAMBU'CUS, Elder

Shrubs or small trees with pinnately compound leaves of 5–11 serrate leaflets. Flowers small, white, in compound cymes. Corolla wheel-shaped or urn-shaped, with 5 lobes. Stigmas and cells of the ovary 3–5. Fruit consisting of "berries," which are really drupes.

a. **S. glau'ca Nutt.** Cymes large and flat. Berries dark-blue, with a dense bloom. This blooms in summer and is common in middle and southern California.

b. **S. callicar'pa Greene.** Cymes ovate. Berries red, rarely yellow. This blooms in spring and is found only in ravines or along streams. Northward.

CUCURBITA'CEÆ. Gourd Family

Herbs, with succulent stems, climbing by tendrils. Leaves palmately lobed, without stipules. Flowers monœcious or diœcious. Calyx adnate to the ovary, with 5 lobes or teeth. Corolla with petals more or less united. Ovary 3–5-celled, stigmas 3–5-lobed. Fruit dry or fleshy. This family contains the Squash, Melon, Cucumber, Pumpkin, and Gourd.

ECHINOCYS'TIS (MEGARRHI'ZA, MICRAMPELIS), Big Root, Chilicothe

The California species are rapidly growing vines, springing from enormous fleshy roots. Flowers small, white, monœcious. Sterile flowers in racemes, at the base of which are the solitary fertile flowers (often they are wanting). Corolla wheel-shaped or bell-shaped. Fruit round or oblong, spiny, the cells within with fibrous walls. Seeds round, flattened. Cotyledons thick, not coming above the ground in germination.

a. **E. faba'cea Naudin.** Flowers yellowish white, numerous; *fruit round, densely covered with long, stout spines.* Seeds 4. This is the commonest species.

b. **E. ma'ra Cogn.** Flowers larger and purer white than the above, less numerous; *fruit pointed at both ends, sparingly covered with spines.* This is a more luxuriant plant than the preceding, and is less common, found chiefly around San Francisco.

c. **E. Orego'na Torr.** *Fruit ovate-oblong,* 1–2 inches long, sparingly clothed with soft spines, with 3–4 cells, each 3-seeded. *Fertile flowers with abortive stamens.* This is common in Washington.

d. **E. macrocar'pa Greene.** *Fruit oblong, densely covered with long, rather soft, stout spines. Seeds several, more than 4.* Central and southern California.

VALERIANA'CEÆ. Valerian Family

Herbs with a disagreeable odor, opposite leaves without stipules, and flowers in cymes. Calyx tube adnate to the ovary, teeth none, or becoming feathery. Corolla with a tube and a 2-lipped border. Stamens 1–3 on the corolla. Style and filaments slender. Stigma entire or minutely 3-cleft. Fruit an akene with the seed hanging.

VALERIANEL'LA

Low annuals with stems generally simple, and flowers in cymes forming whorls at intervals along the stem. Corolla rose-color, small, with tube swollen at base, or with a spur and a 2-lipped border. *Calyx without a border.* The species are few but somewhat difficult to distinguish.

VALERIA'NA, Valerian

Perennials, with simple stems. Flowers small, in terminal panicles or cymes. Corolla white or pale pink. *Calyx limb of 5–15 bristle-like lobes, which are curled up when the flower is in bloom, but spread out, becoming feathery in fruit.* Stamens 3.

a. **V. sylvat'ica Richardson.** Stems erect, a foot or two high, from running rootstocks. Root leaves simple, on long, slender petioles, or compound. Stem leaves pinnately divided into 3–11 leaflets, which are entire or sparingly toothed. Cymes closely flowered, more open in fruit. Flowers light-pink or white, $\frac{1}{4}$ in. long. In the mountains, from middle to great elevations. Summer.

CAMPANULA'CEÆ. Harebell Family

Herbs with milky juice. Leaves alternate, without stipules. Calyx adnate to the ovary, persistent. Corolla usually blue, withering and persisting. Stamens generally 5, inserted at the base of the corolla and alternate with its lobes, ripening before the pistil. Stigma with 2–5 lobes, which do not expand until some time after the flower opens. Style hairy, so as to collect the pollen. Capsule 2–5-celled, with axillary placenta, opening by holes at the top or on the sides.

I. GITHOP'SIS

Low, simple or branched annuals, with small blue flowers. Calyx with a 10-ribbed tube and 5 long, narrow, leaf-like lobes.

Corolla tubular bell-shaped, 5-lobed. Stamens with short filaments dilated at the base. Pistil with three stigmas and a 3-celled ovary. *Capsule long and narrow, firm in texture and strongly ribbed, crowned by the persistent calyx lobes, opening by a hole at the top left by the falling away of the base of the style.*

G. specularioi′des Nutt. Leaves linear, sessile, coarsely toothed. Corolla deep blue with a white center. Flowers on short peduncles at the ends of the stems and branches. This is widely distributed, but not conspicuous.

II. CAMPAN′ULA, Harebell

Perennial herbs with determinate inflorescence. Calyx lobes narrow. Corolla blue, bell-shaped, 5-lobed. Stamens 5, with the filaments dilated at base. *Capsule short and roundish, 3–5-celled, opening on the sides or near the base by 3–5 small, uplifted valves, leaving round perforations.*

a. **C. prenanthoi′des Durand.** Stems clustered, slender, a foot or two high. Leaves ovate-oblong, coarsely serrate, those on the stem mostly sessile, the lower ones on short petioles. *Pedicels shorter than the flowers.* Calyx lobes much shorter than the corolla. Style conspicuously extending beyond the corolla. This is found in moist, shady places in the foothills of the Sierra Nevada Mountains and in redwood forests along the coast.

b. **C. Scou′leri Hook.** Stems slender, branching, a foot or so high, smooth or slightly pubescent. Leaves ovate, pointed, sharply serrate, tapering to a petiole. *Flowers on long pedicels, somewhat panicled.* Corolla oblong in bud, exceeding the slender calyx lobes, deeply 5-cleft, with ovate-oblong lobes. In shady woods from middle California north to British Columbia.

LOBELIA′CEÆ. Lobelia Family

Low herbs with milky juice. Leaves simple, alternate. Flowers scattered or in racemes. Calyx 5-lobed, adnate to the ovary or only to its lower half. Corolla irregular, apparently 2-lipped, inserted, with the free part of the calyx, on the ovary. Stamens 5, alternate with the lobes of the corolla. Filaments united into a tube at the base and usually even to the top. Style 1, stigma 2-lobed. Ovary 2-celled with an axillary placenta, or 1-celled with parietal placentæ. Capsule many-seeded, the seeds with endosperm.

DOWNIN'GIA, GARDENERS' NAME Clinto'nia

Low and spreading smooth annuals, growing in low, wet places that gradually dry ("hog wallows"). Leaves small, sessile, entire, becoming bracts above. Calyx tube and ovary very long and slender, becoming twisted, the divisions of the calyx linear and leaf-like. Corolla 2-lipped, the smaller lip of 2 narrow, recurved, or spreading divisions; the other broad, 3-lobed, deep blue, with a white or yellow center. Filaments and anthers united into a curved tube. Capsule long and slender, becoming 1-celled, splitting along the sides but closed at the top.

a. **D. el'egans Torr.** Low, with ovate to lanceolate leaves, acute. *The smaller lip of the corolla of 2 lanceolate divisions;* the other 3-lobed, blue with a white center. Northern California to Washington and Idaho.

b. **D. pulchel'la Torr.** Stems 3–6 in. high. Leaves lanceolate, obtuse. The *smaller lip of the corolla with 2 oblong divisions;* the other broad, 3-lobed, azure blue, with a large white or yellow spot in the center. Through middle California to Oregon.

COMPOS'ITÆ. Composite Family

Flowers in a dense head, on a common receptacle, surrounded by an involucre composed of many bracts (*f.* Fig. 133; *e.* Fig. 110), with usually 5 stamens inserted on the corolla; the anthers united into a tube which surrounds the style (*f.* Fig. 153; *e.* Fig. 131). Calyx with its tube adnate to the ovary, the limb sometimes wanting, when present taking the form of scales, bristles, etc., known as pappus. Corolla either strap-shaped, 2-lipped, or tubular (*f.* Fig. 147; *e.* Fig. 110), in the first case often 5-toothed, in the last usually 5-lobed. Style 2-cleft above. Fruit an akene, often provided with means of transportation (*f.* Fig. 267; *e.* Figs. 174, 178, 179). The largest family of flowering plants and among the most specialized for insect fertilization. The genera here included belong to the three suborders: I, LIGULIFLORÆ, the corollas all strap-shaped and flowers all perfect; II, LABIATIFLORÆ, corollas of all or only the perfect flowers 2-lipped; III, TUBULIFERÆ, corolla of the perfect flowers tubular and 5-lobed. To the latter belong nine tribes, eight of which are represented by the plants included. The figures refer to illustrations in Part I.

KEY TO THE SUBORDERS AND TRIBES OF COMPOSITÆ

SUBORDER I. — LIGULIFLO'RÆ. All flowers ray flowers. Herbs with milky juice.

SUBORDER II. — LABIATIFLO'RÆ. Corollas of all or only the perfect flowers 2-lipped. Receptacle naked; anthers with conspicuous tails; style branches short, smooth, without appendages.

SUBORDER III. — TUBULIFLO'RÆ. Flowers tubular, the outer ones only with rays, or the ray flowers entirely wanting. The accompanying figures are to illustrate the descriptions of the several tribes. They represent the style branches and anthers as seen when magnified.

Tribe 1. EUPATORIA'CEÆ. Heads without rays. Flowers all perfect, never yellow. Anthers without tails. Style branches club-shaped.

Tribe 2. ASTEROI'DEÆ. Heads with or without rays. Anthers without tails. Style branches of disk flowers flat, tipped with an appendage. Leaves all alternate.

Tribe 3. INULOI'DEÆ. Heads usually without ray flowers. Anthers with tails. Style branches of perfect flowers neither truncate nor tipped with an appendage.

Tribe 4. AMBRO'SIÆ. Heads without ray flowers. Anthers distinct, not united. Style abortive, truncate. Corolla of female flowers rudimentary or wanting. Pappus none.

Tribe 5. HELIANTHOI'DEÆ. Anthers without tails. Style branches of perfect flowers truncate or tipped with an appendage. Bracts of the involucre not papery. Pappus never capillary. Receptacle with chaffy scales mixed among the flowers or only near those on the outside.

Tribe 6. HELENIOI'DEÆ. Similar to *Helianthoideæ*, but there are no chaffy scales on the receptacle.

Tribe 7. ANTHEMOI'DEÆ. Similar to *Helianthoideæ*, but the involucre consists of papery bracts in regular rows, the pappus is a short crown or wanting, and the receptacle rarely has chaffy scales mixed with the flowers.

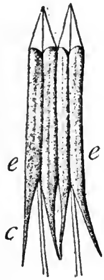

FIG. 5.

FIG. 6.

FIG. 7.

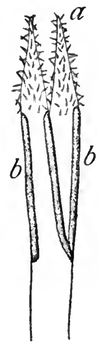

FIG. 8.

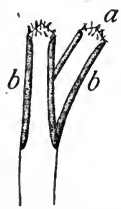

FIG. 9.

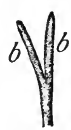

FIG. 10.

FIG. 11.

Fig. 5. Anthers with tails (*c*, tails).—Fig. 6. Anthers without tails (*d*, base of anthers).—Fig. 7. Style and stigma of *Tribe 9*.—Figs. 8, 9. Flat style branches tipped with an appendage (*a*, appendages).—Fig. 10. Style branches of *Tribe 3*.—Fig. 11. Truncate style branches.—*e*, the part of the anthers containing the pollen; *b*, the stigmatic part of the style.

Tribe 8. SENECIONI'DEÆ. Similar to *Helianthoideæ*, but the pappus is abundant and capillary and the receptacle is destitute of chaffy scales. The bracts of the involucre are generally in a single series.

Tribe 9. Cynaroi′deæ. Anthers either with tails or arrow-shaped. Style branches without tips or appendages, often united at the apex. Corollas all tubular, with long, narrow, linear divisions. Receptacle densely bristly.

Suborder I. — **LIGULIFLO′RÆ**

All the flowers ray flowers. Herbs with milky juice. The flowers are generally closed in the afternoon.

I. CICHO′RIUM, Chicory

Perennial herbs with long, spreading branches. Leaves radical and alternate, toothed or pinnatifid. *Heads an inch or more in diameter, bright blue, in the axils of the leaves.* Bracts of the involucre in 2 series, firmly enclosing the ripe akenes. *Pappus 1 or 2 series of short, obtuse scales.*

C. In′tybus L. This is very beautiful in the summer and fall. The stems become garlands of bright blue flowers. It has escaped from cultivation.

II. HYPOCHÆ′RIS, Cat's Ear

Annual or perennial herbs, with the leaves all radical, and forming a rosette at the base of the stem. *Stems naked, branching, terminated by heads of yellow flowers.* Bracts of the involucre in rows; receptacle with chaffy scales that fall soon. *Pappus consisting of 1 row of feathery hairs and an outer row of short, stiff bristles.* The two species are introduced.

a. **H. gla′bra L.** Annual. Stems several, slender, erect. Heads rather small, with the involucres as long as the flowers. Widely distributed.

b. **H. radica′ta L.** Perennial. Stems many. Heads much larger, the involucres shorter than the flowers. Not quite so common as the preceding.

III. TRAGOPO′GON, Oyster Plant, Salsafy

Smooth herbs from fleshy tap-roots. Leaves thin, lax, sessile, tapering to a long point. *Heads large, with purple* *flowers*, bracts of the involucre in one series, united at the base and generally longer than the flowers. *Akenes with long beaks and plentiful brownish pappus hairs, that are feathery, with naked tips, and so numerous that they interlace.*

T. porrifo′lius L. This is common, having escaped from cultivation. The large purple heads are on thick, hollow stems. The flowers soon fade.

IV. MICRO′SERIS

Low herbs, with leaves chiefly radical and heads of yellow flowers on naked stems, mostly *nodding before opening.* Akenes ribbed, truncate at apex; *pappus of several papery scales that spread in fruit.* The species are rather difficult to distinguish.

V. STEPHANOME′RIA

Herbs with smooth, almost leafless branches. Heads of *pink flowers,* numerous, sessile, scattered along the naked stems, in bloom only in the morning. *Akenes 5-ribbed, truncate at both ends, with plumose bristles.*

S. virga′ta Benth. This is simple or widely branched, and often grows to a height of several feet. The bracts of the involucre are in a single row, with a few loose ones at base. This is in bloom through the summer and fall. Widely distributed.

VI. RAFINES′QUIA

Annual, smooth herbs, with leafy, branching stems, and heads of *white or flesh-colored flowers* an inch in diameter, terminating the branches. Akenes terete, gradually narrowed to a slender beak. *Pappus white, cobwebby.*

R. Califor′nica Nutt. This is the common species, which is widely distributed but seldom abundant.

VII. MALACO′THRIX

Generally annual, with leafy or scape-like stems. Flowers various. *The akenes have the apex developed into a crown, and the silky pappus bristles falling in a ring.*

a. **M. Coul'teri Gray.** Erect, with glaucous stems and leaves. *The bracts of the involucre are broad, blunt, shining, and papery, with a green midrib, loosely arranged in several rows;* the flowers are white, turning pink in drying or fading. This is one of the most noticeable annuals of the San Joaquin Valley.

b. **M. Califor'nica DC.** *Annual, with the heads large, solitary at the ends of scape-like stems,* the leaves all radical and pinnately parted into narrow, linear divisions. Flowers yellow. The scales of the involucre are linear and loosely ranked. Pappus of 2 persistent bristles and minute-pointed teeth between. This generally grows in sandy soil, and is most common in southern California.

c. **M. saxa'tilis T. & G.** Perennial, with leafy, branching stems, 1–4 ft. high. Leaves entire or cut into slender divisions from lanceolate to thread-like, in some varieties quite fleshy. Heads many-flowered, an inch or less in diameter, terminating the branchlets, white turning to rose-color. Involucres of numerous, narrow bracts extending down onto the peduncle. Akenes ribbed, the summit with a border of minute white teeth. This is common in southern California, blooming in summer and fall, and in several varieties from the seacoast to the higher hills.

VIII. TROX'IMON, Western Dandelion

Perennial herbs, with radical leaves and *heads of yellow flowers on hollow scapes.* Akenes with smooth ribs and a long beak; *the bristles of the capillary pappus falling singly.* The involucre consists of bracts in several series.

IX. TARAX'ACUM, Dandelion

Similar to *Troximon. The akenes have a long beak and the bristles of the pappus persist on the akene.* The only species is not native.

X. SON'CHUS, Sow Thistle

Herbs with spiny leaves, and erect, branching stems. Heads with the bracts in several series, and flowers yellow. *Akenes flat, with soft, silky-white, capillary pappus.*

a. **S. olera'ceus L.** Leaves pinnatifid, tipped with soft spiny teeth, tapering from an auricled base to a long point, the auricles acute, *akenes rough.* This is a very common introduced weed.

b. **S. as′per Vill.** Erect, more robust than the preceding, with leaves decidedly spiny; the auricles of the leaves are rounded. The *akenes are smooth with sharp edges.* This is less common than the preceding.

SUBORDER II. — LABIATIFLO′RAE

Corollas of all or only the perfect flowers 2-lipped. Receptacle naked; anthers with conspicuous tails; style branches short, smooth, without appendages.

PERE′ZIA

Herbs with alternate, rigid leaves. Flowers solitary or in panicles, purple or white, all perfect. Involucre with leathery scales in several ranks. Corolla with slender tube; the outer, longer lip 3-toothed; the inner 2-toothed or 2-cleft. Anthers with long, naked tails at base and a lanceolate appendage at apex. Akenes usually glandular. Pappus of rough, hair-like bristles.

P. microceph′ala Gray. Stems 2–3 ft. high, branching, glandular at the upper part, leafy to the top. Leaves thin, veiny, oblong to ovate, clasping by a heart-shaped base; margin with minute spine-tipped teeth. Heads numerous in corymbs at the ends of the panicled branches. Flowers rose-purple. This is common in southern California, blooming in the summer and fall.

SUBORDER III. — TUBULIFLO′RÆ

Flowers tubular, the outer ones only with rays, or the ray flowers entirely wanting.

Tribe 1. EUPATORIA′CEÆ. Heads without rays. Flowers all perfect, never yellow. Anthers without tails. Style branches club-shaped.

I. BRICKEL′LIA

Herbs or low shrubs, with opposite or alternate, veiny leaves. Heads few- to many-flowered; bracts of the involucre somewhat papery, in regular rows, nerved with parallel rows or veins. Receptacle naked. Corollas slender, 5-toothed at summit, with the teeth glandular on the outside. Pappus a single row of feathery or rough bristles. Flowers white, greenish or pinkish.

B. Califor′nica Gray. Stems 2–3 ft. high, with wand-like branches, usually growing in bunches. Leaves ovate, obtuse, crenate-dentate, about an inch long. Heads in axillary clusters, together forming an interrupted, erect panicle. Common through California, often growing in the gravelly beds of streams. Blooming in the summer and fall.

Tribe 2. ASTEROI′DEÆ. Anthers without tails. Style branches of disk flowers flat, tipped with an appendage. Leaves all alternate.

II. GRINDE′LIA, Gum Plant

Coarse, resinous herbs, with toothed leaves, large heads with yellow rays and disk, in bud covered with a drop of milky-looking resin. Scales of the broad involucre in several series, with green, spreading tips. Akenes compressed. *Pappus of a few bristles that fall off easily.* This is the most recommended cure for the poisoning from Poison Oak. There are several species difficult to determine.

III. LESSIN′GIA

Much-branched, slender-stemmed plants, *with numerous small rayless heads of yellow, purple, or white flowers on slender peduncles, the corollas of the outside flowers having the lobes usually elongated and unequal.* Involucre silky-hairy. *Pappus a single row of stiff rough bristles.* They bloom in the summer, and the flowers deck the stems like small rosettes.

a. **L. Germano′rum Cham.** YELLOW LESSINGIA. Low and spreading, with heads of *yellow flowers.* Outer corollas with lobes unequal.

b. **L. lepto′clada Gray.** Stems from a few inches to 2 ft. high, much branched, *with numerous, very slender, smooth branchlets,* terminated by the *heads of lilac or white flowers.* Lobes of the corolla equal, the tube as long as the pappus. This is widely spread and very variable. The lower leaves are frequently dry when the plant is in bloom. They are spatulate, toothed, white-woolly; the upper are triangular-ovate and closely sessile. Western and central California. Variable.

IV. CHRYSOP'SIS, Golden Aster

Perennial herbs with many stems from the root, very leafy, with alternate, sessile leaves. *Heads either with or without rays,* solitary or in corymbs. Bracts of the involucre in several series, either with or without papery margins, and without green tips. *Flowers yellow.* Akenes compressed, hairy. *Pappus usually double; the inner a row of long, rough, rusty bristles;* the outer a row of short, narrow, chaffy scales or bristles.

a. **C. sessiliflo'ra Nutt.** Hairy or soft-woolly, with stems a foot or so high. Heads about an inch in diameter, with rays. There are several varieties of this which are considered species by some botanists. Common, and in bloom all the year.

b. **C. Orega'na Gray.** Stems spreading, branched above, rough-hairy. Heads numerous without rays, the involucre almost equaling the flowers. The outer pappus consists of slender bristles rather than chaffy scales. This is found in dry stream-beds through middle California to Washington.

V. APLOPAP'PUS

Herbs or shrubs, with numerous heads of yellow flowers, *the outer ones having rays* (with one or two exceptions). *Bracts of the involucre in several series. Akenes narrow, with pappus in one row.* Receptacle honeycombed.

a. **A. linearifo'lius DC.** Shrubby, much branched, forming a bushy plant. *Leaves an inch or less long, sometimes in clusters, viscid, and covered with resinous dots.* Heads solitary at the ends of the numerous branchlets, an inch or more in diameter, with the ray flowers irregularly placed, so that the head has an untidy appearance; the bracts of the involucre are also less regular than in other species. Akenes silvery-hairy, with white pappus that falls readily. On dry hills in the Coast Mountains.

b. **A. ericoi'des Hook. & Arn.** *Shrubby, much branched, with low, spreading branches.* Heads small, numerous, with few yellow flowers and but few rays. *Leaves very numerous, small, terete, closely clustered into small, somewhat fan-shaped bunches, which rather densely clothe*

the stem. This is common on sand-hills along the coast. (There are many other species quite dissimilar in general appearance.)

VI. BIGELO′VIA, Rabbit-brush

Herbs or shrubs with numerous small heads of yellow flowers, *without rays.* Involucres narrow, with bracts arranged one above the other in rows not always distinct, without green tips. Akenes narrow, usually nerved. *Pappus of almost equal bristles. The heads are generally in close compound cymes, terminating the stems.*

B. arbores′cens Gray. Shrubby, several feet high, with many erect branches from a woody stem. Leaves linear, almost thread-like, thickly clothing the stems, covered with resinous dots. On dry hills of the Coast Mountains, rarely in the Sierra Nevada Mountains.

VII. SOLIDA′GO, Golden-rod

Perennial herbs with erect stems and small heads numerous in panicles. Bracts of the narrow involucre not spreading, in several rows, the outer ones regularly diminishing. *Outer flowers with small rays. Pappus in one row, dull white, rough and capillary.*

a. **S. Califor′nica Nutt.** *Stems and leaves hoary and rough to the touch, covered with a fine, close pubescence.* Stems from 1 to 3 ft. tall, terminated by the numerous heads of pale-yellow flowers in a close panicle, sometimes pyramidal and more branched. This grows on dry ground, throughout California.

b. **S. spathula′ta DC.** *Stems and leaves glutinous* (sticking to the paper when pressed), *dark-green.* Stems 1–2 ft. tall, terminated by a spike-like panicle of rather few heads, which are larger than those of the other species. *Lower leaves spatulate,* rounded at the apex and serrate, 2–4 in. long. This grows near the coast.

c. **S. elonga′ta Nutt.** *Stems leafy, with thin, lanceolate, serrate leaves, 2–3 in. long.* Heads small, in more open panicles than the two preceding. Involucre with linear bracts. This is widely distributed, growing along streams and in gulches.

VIII. AS′TER

Perennial herbs with solitary or clustered heads of flowers with rays which are never yellow. The bracts of the involucre are in several rows, and have green and often leafy tips. Akenes compressed, 4 or 5 nerved. Pappus dull white or tawny, of numerous rough, capillary bristles, in a single row. *The disk flowers are yellow, often turning purple, and the rays are white, blue, pink, or purplish.*

a. **A. raduli′nus Gray.** Stem simple below, from a few inches to 1 or 2 ft. high, leafy, *branching above to an open corymb of medium-sized heads.* Leaves diminishing towards the top, stiff and rough, oblong or broadly spatulate, sharply serrate near the top, tapering below. Bracts of the involucre stiff, appressed, with green tips often glandular. *Rays white, the disk corollas becoming reddish.* Pappus rigid. Monterey County to Washington.

b. **A. Chamisso′nis Gray.** Stems 2–5 ft. high, leafy and branching, *terminated by numerous medium-sized heads in long racemes or in widely branching panicles.* Leaves lanceolate, 2–5 in. long, entire or slightly serrate, sessile. Bracts of the involucre in several ranks, with short and rounded tips. Rays white, purple, or violet, 20–25, nearly half an inch long. This is the most widely distributed species. It is somewhat variable in the size and color of the rays and also the inflorescence. Throughout California to Oregon.

IX. ERIG′ERON

This is similar to *Aster,* but *the bracts of the involucre are in a single row, or if there is more than one the ranks are not distinctly apparent.* The pappus is often in two rows, and the rays are generally more numerous and narrower.

a. **E. glau′cus Ker.** SEASIDE DAISY. Generally, low, perennial herbs, growing in mats near the seacoast. Leaves and stem covered with soft, spreading hairs. Leaves broad, entire; the upper ones sessile, the lowest narrowed to a margined petiole. Heads an inch or two in diameter, with numerous violet or white rays, and the involucres soft-hairy and somewhat viscid. The stems are terminated usually by solitary heads; sometimes there are 3 or 4 in a cluster. This is common on the coast, and in bloom throughout the year.

b. **E. Philadel′phicus L.** Perennial herbs, with stems from 1 to 3 ft. tall, hairy. Root leaves spatulate or obovate, those on the stem oblong, sessile by a broad, clasping base, irregularly toothed. *Heads in a loose corymb, with numerous very narrow pinkish rays.* This is common in wet places.

c. **E. folio′sus Nutt.** Perennials, with several stems from a woody root, simple, very brittle, and leafy up to the corymb, with a rough, grayish pubescence. *Leaves narrow, an inch or two long, entire, diminishing upwards.* Heads with unequal bracts to the involucre and about 30 bluish rays. Inner pappus capillary, outer of a few short bristles. Throughout California. Extremely variable.

d. **E. Canaden′sis L.** FLEABANE. Annual with stems from 1 to 6 ft. tall. Heads very small, numerous in a loosely and much-branched panicle. Leaves mostly linear, numerous. *Rays white, inconspicuous.* This grows everywhere and is a common weed.

X. BAC′CHARIS

Diœcious shrubs having numerous heads without rays and with the scales of the involucre in several rows. Pappus capillary in one row, very abundant on the female flowers.

a. **B. pilula′ris DC.** Stems much branched, erect, several feet high, in bunches often forming thickets, or (on the coast hills) low and spreading. *Leaves sessile, wedge-shaped, dark-green, coarsely toothed.* Heads either solitary or two or three in a cluster in the leaf axils, very numerous. Male heads yellowish white, the stamens conspicuous, slightly surpassing the involucre. Female flowers noticeable, because of the long snow-white pappus, which is much longer than the involucre. This is very common along the entire coast in sandy soil. It blooms in autumn and is often covered with small gall-nuts.

b. **B. Douglas′ii DC.** Shrubby at base, glutinous, the herbaceous branches terminated by compound corymbs. *Leaves lance-shaped, acute, 3-nerved.* Scales of the involucre broader in the male heads than in the female, hairy on the margin. Receptacle conical. Flowers whitish. Common from San Francisco southward, along streams.

c. **B. vimin′ea DC.** FLOWERING WILLOW. *Shrubby, resembling a willow, with woody branches.* Stems 4–20 ft. tall. Leaves lance-shaped, acute at both ends, entire or with a few teeth. Heads numerous in corymbs terminating the branches. Scales of the involucre very thin, with hairy, papery margins. Receptacle flat. This is found along streams from Monterey southward.

Tribe 3. INULOI′DEÆ. Anthers with tails. Style branches of perfect flowers neither truncate nor tipped with an appendage. Ray flowers wanting in the Californian species.

XI. PLU′CHEA, Marsh Fleabane

Annual herbs growing in salt or alkaline marshes, glandular, a foot or two high. *Heads numerous in dense corymbose* *cymes. Bracts of the involucre purplish, thin and dry, in several ranks.* Most of the flowers are fertile, the sterile ones in the center are purplish or sometimes white. Pappus of fine, capillary bristles, in a single row.

P. camphora'ta DC. Leaves oblong-ovate to broadly lance-shaped, nearly sessile, irregularly toothed. The entire plant has a heavy, aromatic odor. In salt or alkaline marshes.

XII. ANAPH'ALIS, Pearly Everlasting

Diœcious, perennial herbs, with white-woolly foliage. *Involucre of many rows of snow-white, papery scales.* Style 2-cleft, only at the apex. Pappus a single series of capillary bristles falling separately.

A. margarita'cea Benth. & Hook. Stems 1–3 ft. high, leafy up to the broad compound corymb. Leaves narrow, lance-shaped, 1-nerved, becoming green and smooth above. Scales of the involucre pearly white, not longer than the flowers. Widely distributed.

XIII. GNAPHA'LIUM, Everlasting, Cotton-batting Plant

Annual or perennial white-woolly herbs, with whitish or yellowish flowers. *Heads with both staminate and pistillate flowers, the latter fewer and in the center. Involucre of several ranks of papery or papery-tipped scales.* Styles in perfect flowers, 2-cleft. Pappus of capillary bristles in a single row.

a. **G. decur'rens Ives.** Stems usually several from the woody root, 1–3 ft. high and rather stout, *glandular under the dense wool. Leaves lance-shaped, with the blade extending down the stem.* Heads many in dense corymbs terminating the stems. Involucre bell-shaped, of many papery scales in several ranks. The plant has a peculiar odor, something like licorice. It is common and widely distributed along the coast.

b. **G. microceph'alum Nutt.** Perennial herbs, with slender, erect stems 2 ft. or more high, loosely branched above, white, with a close wool. Leaves linear, the lowest spatulate. *Involucre small, with bright, white, obtuse bracts. The herbage is odorless, not glandular.*

c. **G. ramosis'simum Nutt.** Perennial herbs with erect stems, 3–6 ft. high, viscid, green, with woolly covering not abundant. Heads in loose panicles, small, *often with pink involucres.* Leaves lance-shaped, with the blade extending down the stem. *The entire plant has a pleasant aromatic odor.* Common on hills near the coast, blooming in summer.

There are several species besides these that are quite common.

Tribe 4. AMBRO'SIÆ. Anthers distinct or slightly united. Style abortive, truncate. Corolla of female flowers rudimentary or none. Staminate heads generally in a cluster above the pistillate ones. Receptacle with chaffy scales.

XIV. FRANSE′RIA

Monœcious. Staminate heads in many-flowered racemes. Scales of the involucre united into a cup ; receptacle with thread-like scales among the flowers. *Female flowers usually one or few in the leaf axils, each surrounded with a spiny involucre.* Akenes enclosed in the persistent involucres, which form burs.

a. **F. bipinnatif′ida Less.** Low spreading, perennial herbs, with grayish pubescent stems and leaves. Leaves twice or thrice pinnately divided into roundish divisions. On the coast from Washington to San Diego.

b. **F. Chamisso′nis Less.** Similar to the above, with which it seems to mix. The leaves are ovate or wedge-shaped, with obtuse teeth. These two species grow on the sand dunes of the coast and are frequently associated.

XV. XAN′THIUM, Cocklebur

Monœcious. Male heads many-flowered, with the scales of the involucre distinct in one series ; receptacle cylindrical. *Female heads united and enveloping the akene, armed with hooked spines.* These are stout annual herbs, with an abundance of large burs in the fall.

a. **X. struma′rium L.** Leaves broadly ovate, cordate, green on both sides, on long petioles, rough, irregularly toothed. Burs $\frac{3}{4}$ in. long, ovate, *tipped with two stout beaks.* Common, introduced.

b. **X. spino′sum L.** Stems much branched, very spiny, with long triple yellow spines by the sides of the leaves. Leaves lanceolate, white beneath, twice or thrice lobed or cut, tapering into short petioles. Burs flat, less prickly and with weaker prickles than the preceding, and *inconspicuous beaks.* Common, introduced.

Tribe 5. HELIANTHOI'DEÆ. Anthers without tails. Style branches of perfect flowers, truncate or tipped with an appendage. Bracts of the involucre not papery. Pappus never capillary. Receptacle with chaffy scales mixed among the flowers or only near those on the outside.

XVI. WYE'THIA, California Compass Plants

Perennial herbs with simple stems from a stout rootstock. Leaves alternate, large, the same on both sides, erect, the edges pointing north and south. *Heads usually solitary, large, with long broad, yellow rays.* Bracts of the involucre in 2 or 3 rows, the outer leaf-like, the inner thinner and somewhat membranous. Receptacle flat, with the chaffy scales partially folded around the akenes. *Pappus forming a cup on top of the akene, or of from 1 to 4 rigid chaffy awns.* These plants bloom early in the flowering season.

a. **W. helenioi'des Nutt.** *Stems and leaves white-woolly when young.* Leaves all on short petioles, the lowest a foot or two long, 4–8 in. wide. Heads large, 4 in. or more in diameter, leafy at base. Akenes pubescent towards the apex. Pappus scales more or less united into a cup. In bloom early. Around San Francisco Bay on hillsides.

b. **W. gla'bra Gray.** *Similar to the preceding, but the whole plant is smooth and somewhat glutinous, the leaves are leathery and dark-green.* Akenes smooth. In bloom in April and May. In the Coast Mountains, from Marin County southward.

c. **W. angustifo'lia Nutt.** *Radical leaves long-lanceolate, pointed at both ends.* Heads smaller than the two preceding, on long peduncles, leafy only at base. Bracts of the involucre numerous, lanceolate, hairy on the margin, loose and leafy. Pappus of 1–4 stout hirsute awns, with short intervening scales. This is in bloom the latest. It is common and widely distributed.

d. **W. amplexicau'lis Nutt.** *Smooth. Upper leaves sessile.* Involucre broad, bell-shaped, of many loose scales. *Pappus without bristles.* Eastern Oregon to Washington.

XVII. BALSAMORRHI'ZA, Balsam-root

Perennial herbs with thick aromatic roots and large leaves chiefly from the root. *Heads large, usually solitary and* *terminating almost leafless stems, containing many flowers.* Involucre of many loose leaf-like scales in several ranks. Ray and disk flowers fertile, yellow. Pappus none. *Akene of the ray flowers flattened parallel with the scales; those of the disk with 4 angles.*

a. **B. sagitta′ta Nutt.** *Densely covered with white wool.* Leaves entire, *heart-shaped or arrow-shaped*, 4–8 in. long, on long petioles. Scapes a foot or two high. Rays yellow, 1–2 in. long. In the Sierra Nevada Mountains to British Columbia, blooming in early spring.

b. **B. deltoi′dea Nutt.** *Green and almost smooth.* Leaves broadly *heart-shaped to V-shaped*, irregularly serrate or entire, 4–10 in. long. Scapes with small lanceolate or cordate leaves bearing 1–3 heads. Rays an inch or more long. Southern California to British Columbia, blooming in early spring.

XVIII. HELIAN′THUS, Sunflower

Annual or perennial herbs with the lowest leaves opposite, the upper alternate, all simple. Heads large, with conspicuous yellow rays. Bracts of the involucre in several series, green, but not leaf-like. Receptacle flat, with the chaffy scales numerous. Akenes slightly flattened, 4-sided. Pappus of 2 marginal scales that fall soon, and more persistent minute bristles between.

H. Califor′nicus DC. Stems tall, 2–5 ft. high, branching above. Leaves long, lanceolate, or broader at base. Bracts of the involucre narrow, linear-lanceolate, tapering to a long-spreading point. Receptacle convex, with the chaffy scales blunt. Akenes flat, with a smooth pappus of 2 or 3 chaffy scales. This grows along streams. The flowers are quite numerous on the branches at the top of the stem. Common from around San Francisco southward. Summer and fall.

XIX. ENCE′LIA

Perennial, shrubby at base, branching. Leaves opposite or alternate, generally simple. Heads containing many flowers; disk flowers perfect; ray flowers generally present and neutral. Involucre bell-shaped with the scales in several rows one above the other. *Akenes flat, with a thin edge but* *without wings, obovate, 2-toothed at summit or notched, with long hairs or without. Pappus none or a pair of bristles.*

E. Califor'nica Nutt. Gray pubescent at first but becoming smoother and greener. Leaves alternate, ovate to lanceolate, 1–2 in. long. Involucre covered with white hairs. Rays an inch long, yellow.

XX. LEPTOS'YNE

Smooth succulent herbs, with leaves twice or thrice pinnately parted into narrow, linear lobes. *Heads on long peduncles, with a double involucre, the outer of 5–8 narrow, leaf-like scales, the inner of 8–12 thinner and broader erect scales. Rays yellow, conspicuous,* oblong, 3-toothed, 10-nerved. Receptacle nearly flat, with thin papery chaff that falls with the fruit. Corollas of the disk flowers with a slender tube having a ring around the summit below the funnel-form border. *Akenes flat, more or less margined with a wing. Pappus none, or a minute cup.*

a. **L. Douglas'ii DC.** Annual. Stems leafy only at base. Heads on long, naked peduncles. *Rings on the corolla tube hairy.* Common in southern California.

b. **L. Still'mani Gray.** Stems leafy below. Involucre hairy at base. *Ring on the corolla tube smooth.* This is the commonest species.

c. **L. marit'ima** and **L. gigante'a** are shrubby, perennial species with thick fleshy stems. The former grows near San Diego on the coast; and the latter, which has a strong odor of turpentine, near the coast in Ventura and San Luis Obispo Counties, and on the islands off the coast of Santa Barbara.

XXI. BI'DENS, Bur Marigold

Annual herbs, usually growing near water. Leaves opposite. Involucre double, as in *Leptosyne.* Receptacle flat or convex, the thin, narrow, chaffy scales falling with the fruit. *Akenes with a pappus of 2–4 awns, barbed downwards.* The species are somewhat uncertain.

XXII. MA'DIA, Tarweed

Annuals with glandular, aromatic foliage and flowers that wilt during the heat of the day. *Bracts of the involucre in* *one series, boat-shaped, and embracing the black or brown flattened akenes.* Receptacle without chaffy scales in the center, but with one or two rows between the disk and the ray. *Ray flowers and usually disk flowers without pappus.* Rays yellow, sometimes with a brown spot at base.

a. **M. el′egans Don.** Stems branching. Heads in loose panicles an inch in diameter, *with conspicuous yellow rays, often with a brown spot at base.* Foliage lemon-scented. Widely distributed.

b. **M. sati′va Molina.** Stems simple or branching. Heads usually densely clustered, *with inconspicuous yellow rays.* The bracts enclosing the akenes persist around the akenes and adhere to other substances by means of their viscidity, thus accomplishing the distribution of the seed. Widely distributed.

XXIII. HEMIZO′NIA, Tarweed

This is similar to *Madia*, the chief difference being the bracts enclosing the akenes, which in *Madia* almost entirely surround the individual akenes, *while in Hemizonia they only half enclose them.* ("Hemizonia" means half zone.) *The disk flowers generally have pappus and the rays are either yellow or white.* Anthers brown.

a. **H. luzulæfo′lia DC.** Annual, widely branching. *Lower leaves long, linear, silvery, with shining white hairs, the upper leaves very glandular.* Heads numerous, with white or yellow 3-lobed rays less than $\frac{1}{2}$ in. long, the dark-brown anthers conspicuous. This is one of the commonest *Tarweeds*, blooming in summer and fall.

b. **H. pun′gens (Centroma′dia).** Stems much branched, hirsute. Lower leaves twice pinnatifid, with short spiny lobes, those on the *branchlets entire, crowded, spine-tipped. Bracts of the involucre spiny, and also the narrow chaff of the receptacle.* Rays about as long as the disk, 2 or 3 toothed. *Pappus none.* This is common, blooming in summer and fall.

c. **H. multiglandulo′sa Gray (Calycade′nia).** Annuals, with erect stems and branches; covered, especially above, with black tack-shaped glands; lemon-scented. Leaves narrowly linear. Heads crowded in the axils of the upper leaves or sometimes solitary. *Flowers white or tinged with rose-color, the rays 1–7, broad, deeply 3-lobed.* Receptacle flat, with chaffy scales only between the ray and the disk flowers. Common in California. The species are very numerous and difficult.

XXIV. LAY'IA, Tidy-tips (BLEPHARIPAP'PUS)

Annual herbs with alternate leaves. Heads many-flowered, with wedge-shaped, 3-toothed rays. Bracts of the involucre in one series, with papery margins and pointed tips, completely enclosing the ray akenes. *Receptacle flat, with a row of chaffy scales between the ray and the disk, or chaffy throughout.* Ray akenes linear, often purplish, narrowed to the base, flat on top, *without pappus.* They bloom in the spring.

a. **L. glandulo'sa Hook. & Arn.** Loosely branching, about a foot high, hairy, and sprinkled above with stipitate, dark-colored glands. *Pappus of disk flowers, of 10–20 stout bristles, that are densely white-woolly below the middle.* Heads medium-sized, with 8–13, 3-lobed, conspicuous *white or rose-purple rays and yellow disk.* Widely distributed.

b. **L. platyglos'sa Gray.** TIDY-TIPS. Loosely branching or often simple-stemmed, hairy, and glandular. Lower leaves pinnately lobed, with narrow divisions. Heads with large rays, *bright yellow, edged with white. Pappus of 15–25 stout, rough bristles, that are not woolly.* Ray akenes smooth, those of the disk silky-hairy. Throughout California. (There are several other species not so easily distinguished.)

Tribe 6. HELENIOI'DEÆ. Similar to *Helianthoideæ*, but without chaffy scales on the receptacle.

XXV. BAE'RIA, Golden Fields (LASTHENIA)

Low annuals with opposite leaves, entire or irregularly pinnatifid into linear lobes. Heads small, on slender peduncles, terminating the branches or stems. Involucre formed of a single series of flat, oblong scales. Rays entire or 3-toothed, oval or oblong. *Receptacle conical, rough, with projecting points that bear the akenes.* Akenes angled or nerved. Pappus either scales or bristles, or none. These little plants cover the ground for acres, and look like a golden carpet spread over the earth. Some species have a sweet, rather heavy perfume.

B. gra'cilis Gray. SUNSHINE. This is the most widely spread species, but it is not easily distinguished from the others. Fragrant.

XXVI. BLENNOSPER′MA

Annuals, low, slender, much branched, smooth. Leaves pinnately parted into many, narrow, linear divisions. Heads small, terminating the branchlets. Flowers many, light yellow. Involucre with bracts in a single series, generally tipped with dark red. *Receptacle flat. Ray flowers pistillate, without pappus ; disk flowers sterile, except the row next to the ray flowers. Akenes covered with white dots which become jelly-like when wet.*

B. Califor′nicum T. & G. This is the only species. It grows in wet places in early spring and often covers the ground for miles along highways.

XXVII. ERIOPHYL′LUM

Shrubs or herbs with entire or divided leaves clothed with cottony wool, especially on the under surface. *Flowers yellow.* Bracts of the involucre lance-shaped, united at base. *Pappus of membranaceous scales.*

a. **E. stæchadifo′lium Lag.** LIZARD-LEAF. Shrubby, with many stems rising from a woody base, terminated by *loose cymes of rather small heads.* Leaves cut into linear, pinnate divisions somewhat resembling a lizard in outline, green above, white below. Common in the Coast Mountains.

b. **E. confertiflo′rum Gray.** Similar to the above, but smaller, with leaves reduced and scattered, white on both sides. *Heads almost destitute of rays in a dense corymb.* Extending to the Sierras, as well as in the Coast Mountains.

c. **E. cæspito′sum Dougl.** Perennial herbs, with many stems from the root. Heads nearly an inch in diameter, with conspicuous rays, solitary or few, on long peduncles. This is extremely variable and widely distributed.

XXVIII. MONOLO′PIA

Annual herbs with woolly pubescence and sessile leaves alternate above, sometimes opposite below. Heads large, terminating the stems ; *scales of the involucre united into a toothed cup. Receptacle conical, papillose. Pappus none.* Flowers yellow, with conspicuous rays.

M. ma′jor DC. Ray corollas, with a broad 3 or 4 toothed or lobed ray, and bearing on the opposite side of the style a roundish, toothed appendage. Leaves simple, partly clasping. Heads nearly 2 in. in diameter, very showy. Throughout western California, in low ground.

XXIX. CHÆNAC′TIS

Herbs with pinnately compound leaves, more or less white-woolly, and heads of yellow, white, or flesh-colored flowers without rays; *the outer corollas often have an enlarged border simulating a ray.* Involucre with green, linear, erect bracts, generally in a single row. *Receptacle flat. Pappus of chaffy scales.* Akenes slender. The heads are solitary, or in loose clusters on peduncles. The species are not easily distinguished.

XXX. HELE′NIUM, Sneezeweed

Annual or perennial herbs with alternate leaves, and heads on peduncles terminating the branchlets. Bracts of the involucre in 2 series, the external scales narrow, leaf-like, spreading, and at length reflexed, the internal scales few and chaffy. *Receptacle globular. Pappus of 5–12 thin, chaffy scales.* Ray flowers yellow, disk flowers often purplish.

a. **H. puber′ulum DC.** Widely branched, the stems winged with the decurrent leaves. Disk forming a round ball, ray flowers inconspicuous. This is common in wet places.

b. **H. Bolan′deri Gray.** Perennial, with stems a foot or two high. Heads on long, naked peduncles which are thickened at top. Leaves obovate or lanceolate. Heads large, with wedge-shaped rays an inch long; disk an inch across. From northern California to Washington.

c. **H. Bigelo′vii Gray.** Stems tall and simple. Leaves lanceolate to oblong or linear, entire. Heads on long, slender peduncles, with rays half an inch long and disk as broad, somewhat depressed. Common in wet places in the Sierra Nevada Mountains of California.

Tribe 7. ANTHEMOI′DEÆ. Similar to *Helianthoideæ*, but the involucre consists of papery bracts in regular rows, the pappus is a short crown or wanting, and the receptacle rarely has chaffy scales mixed with the flowers.

XXXI. AN'THEMIS, Dog Fennel

Herbs with pinnately dissected leaves and numerous heads, terminating the branchlets. Scales of the involucre in several series, one above the other. Receptacle convex or conical, having chaffy scales among the flowers. Ray flowers white, those of the disk yellow. Pappus none. *Akenes ribbed.*

A. Cot'ula L. WHITEWEED, MAYWEED. This is a common introduced weed, and blooms in summer and fall. It has a strong, acrid taste disagreeable to animals.

XXXII. ACHILLE'A, Yarrow, Milfoil

Perennial herbs, strong-scented, with pinnately dissected leaves. *Stems usually simple, terminated by dense corymbs of small heads of white or pinkish flowers.* Involucres with small scales in several rows. Pappus none, *akenes flattened, margined.* Bracts of the receptacle thin and transparent.

A. millefo'lium L. This is common and widely distributed. The leaves are disposed to form rosettes at the base of the stem, and are delicate and fern-like.

XXXIII. MATRICA'RIA, Chamomile

Erect simple or branching herbs, with pinnately dissected leaves. Heads terminating the branches, on short peduncles. Bracts of the involucre in several series. *Disk greenish yellow, conical. Rays white when present. Pappus in a crown or wanting.*

M. discoi'dea DC. MANZANILLA. Annual, erect, branching. Heads with a high conical disk and no rays. Involucre with white, papery margins to the broadly ovate scales. Akenes with a crown-like margin in place of pappus. This plant has the odor of ripe apples. Widely distributed.

XXXIV. ARTEMIS'IA, Wormwood, Sagebrush

Herbs or shrubs with bitter taste and alternate leaves. *Heads greenish, small, without rays, numerous in racemes or panicles.* Scales of the involucre dry, with papery margins.

Receptacle naked or hairy. *Akenes obovate, with a small disk at top, but without pappus.* These have inconspicuous flowers, often an aromatic odor, and they bloom in the fall.

a. **A. vulga'ris var. Californica Besser.** MUGWORT. Stems simple and tall. *Upper leaves toothed or entire, lower 3–5-parted, green on the upper surface, white-woolly below.* This grows in gulches and along streams, and is widely distributed.

b. **A. Califor'nica Less.** FLEABANE. Shrubby, with many branches from a woody base, 3–4 ft. high, forming a clump. Entire plant white-pubescent. *Leaves pinnately divided into thread-like divisions.* This grows on dry hills and is pleasantly aromatic. Common from San Francisco southward.

XXXV. COT'ULA, Brass-buttons

Small introduced annual herbs, having heads without rays. Bracts of the involucre nearly equal, papery on the margins, in 2 ranks. *Receptacle flat, naked, papillose. Akenes flattened, with spongy margins. Pappus none.* Flowers yellow.

a. **C. coronopifo'lia L.** Smooth, with creeping stems and rather fleshy leaves, which are lanceolate, irregularly pinnatifid, toothed or entire, with broad, clasping base. *Heads ½ in. in diameter, flat on top, the bright-yellow disk flowers very numerous.* This grows in wet places, and is very common near the coast.

b. **C. Austra'lis L.** Smaller than the preceding, hairy. Leaves twice pinnately parted into linear divisions. *Heads very small, with flowers greenish.* This grows along the streets and in waste places.

Tribe 8. SENECIONID'EÆ. Similar to *Helianthoideæ*, but the pappus is abundant and capillary, and the receptacle is without chaffy scales.

XXXVI. AR'NICA

Perennial herbs with creeping rootstocks, and simple stems bearing a few rather large heads of yellow flowers on long peduncles and usually *a few opposite, entire or toothed leaves.* Involucre bell-shaped, of linear or lance-shaped equal scales in one or two series. Rays elongated or sometimes wanting. Pappus a single row of stiff, bearded, capillary bristles. Akenes linear, 5-angled, or ribbed.

a. **A. discoi′dea Benth.** *Heads without rays in a bractless panicle.* Involucre hairy and glandular. Leaves ovate or oblong, irregularly toothed, the upper sessile and often alternate. Akenes becoming smooth, not glandular. In the Coast Mountains.

b. **A. cordifo′lia Hook.** *Heads with conspicuous rays*, usually about ½ in. long (rarely rayless). *Leaves opposite, 2 pairs on the stem;* root leaves roundish and deeply cordate, coarsely toothed. In the Sierra Nevada Mountains.

c. **A. folio′sa Nutt.** Perennial, from rootstocks. Stems erect, leafy, clothed with white wool. *Leaves lanceolate, with small blunt teeth on the margin and with 5 parallel longitudinal nerves.* Heads rather small, in corymbs, on short peduncles. Rays short, yellow. Common in the Sierra Nevada Mountains, north to Oregon, blooming in summer.

XXXVII. SENE′CIO, Groundsel

Herbs or shrubs with *alternate leaves* and heads of yellow flowers either solitary or in corymbs. Bracts of the involucre in a single series, somewhat united, *often with a few loose bracts at the base.* Akenes slender, with fine and soft copious pappus.

a. **S. vulga′ris L.** Old Man of Spring. Annual, from a few inches to a foot high. Leaves rather thick, pinnately cut into toothed lobes. Scales at the base of the involucre tipped with black. *Heads small, rayless.* This is common in fields and along roads. An introduced weed.

b. **S. Douglas′ii DC.** *Perennial, sometimes shrubby, leafy to the top,* usually white, with cottony wool more or less persisting. *Leaves linear, entire, acute, or pinnately parted into linear lobes..* Heads in corymbs at the ends of the branches, about an inch in diameter. Involucre with a few loose scales at the base. Rays elongated. Widely distributed.

c. **S. aronicoi′des DC.** Stems stout, erect, leafy at base, with *leaves irregularly and coarsely toothed, 3–6 in. long.* Heads rather small, in compound cymes terminating the stems, without rays or with only one or two. Bracts of the involucre without black tips. Common throughout California in low grounds.

d. **S. euryceph′alus Torr. & Gray.** Stems stout, erect, leafy, somewhat white-woolly when young, becoming smoother with age. *Leaves unequally pinnately parted, with wedge-shaped, acutely incised lobes.* Heads many in an ample corymb, with 10–12 long and showy rays.

e. **S. Califor′nicus DC.** Annual, a foot or two high, with smooth, slender stems. *Leaves linear to oblong ; those on the stem clasping at base ;*

those near the base toothed or lobed. Heads in corymbs, with rays half an inch long. Common in southern California, blooming in spring.

f. **S. triangula′ris Hook.** Stems simple, smooth, leafy, 2–5 ft. high. *Leaves triangular, sharply toothed, pointed at top.* Heads many, in corymbs terminating the stem. Involucre bell-shaped, with a few loose, narrow bracts at base. Rays 6–12, half an inch long. In the Sierra Nevada Mountains to Washington. Summer.

Tribe 9. CYNAROI′DEÆ. Anthers either with tails or arrow-shaped. Style branches without tips or appendages, often united near the apex. Corollas all tubular, with long, narrow, linear divisions. Receptacle densely bristly.

XXXVIII. CIR′SIUM (CNI′CUS), (CAR′DUUS) Thistle

Stout herbs, usually biennial, with alternate prickly leaves and large or medium-sized heads of purple, red, white, or yellowish flowers. Scales of the involucre bristle-tipped, arranged in many series, the lower successively shorter. Receptacle flat, densely clothed with bristles. Akenes smooth, obovate or oblong. Pappus of numerous, long, plumose bristles that are deciduous, united in a ring. The style is usually thickened by a knee-like swelling immediately below the stigmatic portion, which consists of two slender divisions united nearly or quite to the top. The species are not easily determined.

XXXIX. SIL′YBUM, Milk Thistle

Stout annuals, nearly smooth, with large root leaves blotched with white, and prickly on the margins. Heads many-flowered and often solitary. Involucre with leaf-like closely appressed bracts, tipped with stout spines. Flowers magenta-purple. Pappus of stiff, chaffy bristles in several rows, not spiny.

S. Maria′num Gærtn. This has been introduced from the Mediterranean region, and is spreading more and more.

XL. CENTAURE′A, Star Thistle

Herbs with small heads of yellow, rose-color, or blue flowers. Involucre globular, the scales spine-tipped or papery at the apex, generally contracted under the flowers. Receptacle very bristly. Akenes compressed, with pappus of numerous chaffy bristles that fall separately. The outer flowers are often funnel-shaped, with broad conspicuous divisions simulating a ray flower. All the species are introduced weeds from Europe.

a. **C. Meliten'sis L.** TOCALOTE. Annual, with spreading branches. Radical leaves pinnatifid, with rather broad lobes, the stem leaves barely toothed, decurrent. *Corollas yellow, inconspicuous.* Scales of the involucre spine-tipped, and with a few prickles at the base. Common in fields and waste places.

b. **C. solstitia'lis L.** Annual, much branched. Stem leaves linear. *Flowers conspicuous yellow.* Outer bracts of the involucre with 3–5 small prickles, palmately spreading; middle bracts with a stout spine besides. This is less common than the preceding.

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